

Sexual Reproduction in flowering plant

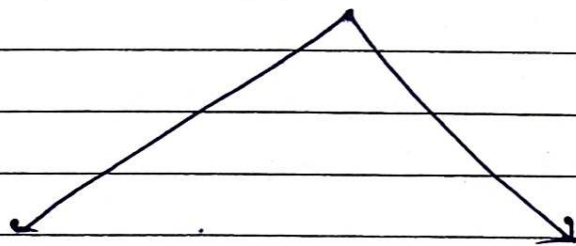
* Sexual reproduction

- Reproduction by gamete formation and fusion of gametes occur in flowering plant $\rightarrow$ Angiosperm (flower, fruit & seed)
- flower $\div$ site of sexual reproduction
- final product of sexual reproduction in flowering plant $\rightarrow$ fruit and seed.
- flower $\div$ aesthetic, social, culture, religions, sorrow etc.
- Home flowering plant $\div$ Rose, chin rose, marigold, lily, jasmine, sunflower.

* Meristem

- Group of cells which are actively dividing (merismatic cells)

Meristem (Apical)



Shoot apical

Root apical

$\rightarrow$ Tip of shoot

$\rightarrow$ Tip of root

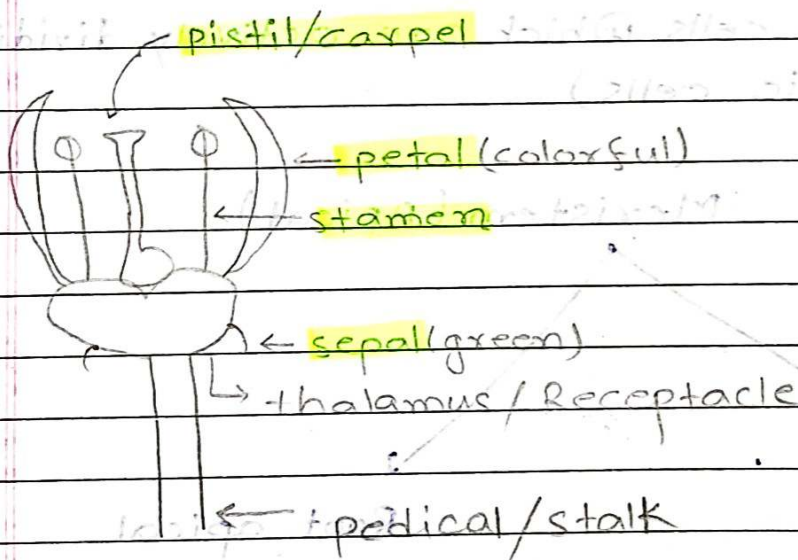
- cells $\div$ shoot apical merismatic cells
- cells $\div$ root apical merismatic cells



* formation of flower

- When hormonal change (florigen, auxin) occur in flowering plant then shoot apical meristem start dividing fast and called floral primordium.
- Floral primordium convert into floral meristem (floral bud)
- Floral bud stop division then differentiated and form flower.

* Structure of flower



- Calyx ÷ First whorl / group
- Corolla ÷ Second whorl
- Androecium ÷ third whorl
- Gynocium ÷ fourth whorl

Floriculture

↳ cultivation and growing of flowering plant



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• (A) & (B) ÷ Essential

• (C) & (D) ÷ Non-essential/Accessory

• Group of sepals ÷ calyx

• " " petals ÷ corolla

• " " Andro stamens ÷ Androcium

• " " pistils ÷ Gynocium

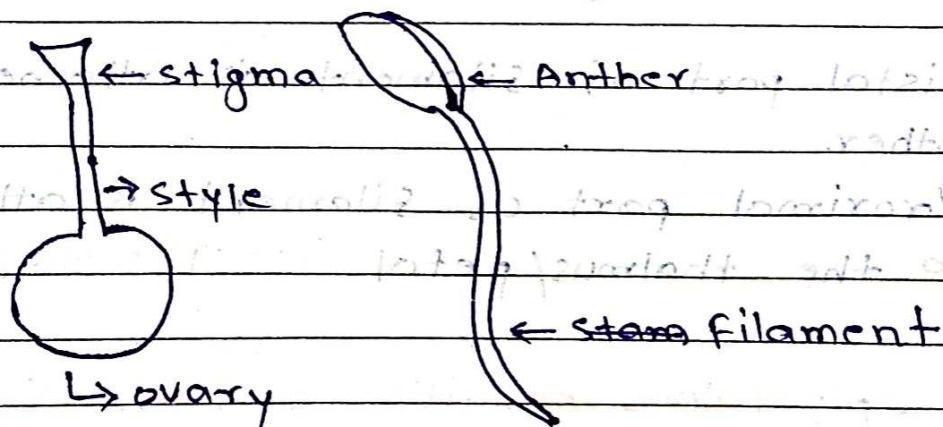
• Calyx, corolla, androcium and gynocium are modified leaf and they are together called floral appendages.

• Androcium ÷ Male reproductive structure
↳ unit ÷ stamen

• Gynocium ÷ female reproductive structure
↳ unit ÷ pistil

• petal attract insect for pollination.

• pistil and stamen.





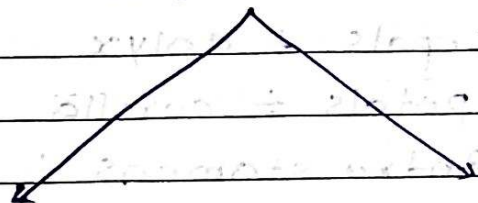
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* Inflorescence

- Arrangement of flowers

Inflorescence



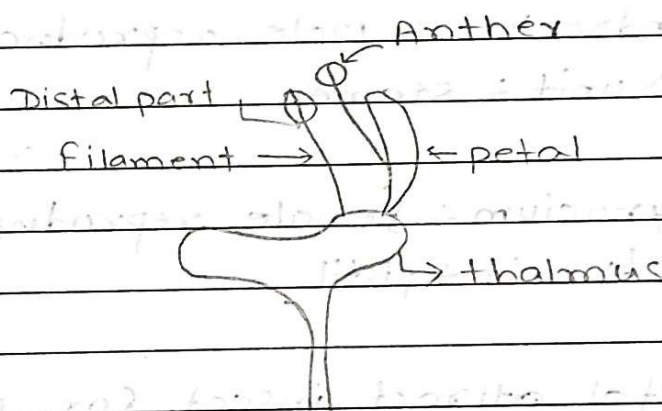
Acropetal order

- older flower at base & younger at top

Basipetal order

- older flower at tip and younger at base

* Stamen



- Stamen consist of two part
- (i) Anther ÷ Bilobed, terminal
- (ii) filament ÷ long, slender

- Distal part of filament is attached to anther.

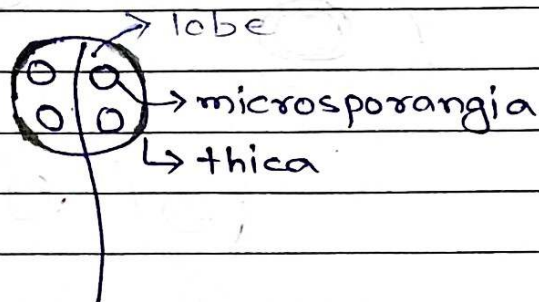
- Proximal part of filament is attached to the thalamus/petal [NEET 2016]

Note ÷ epipetalous condition seen in Solanaceae - family

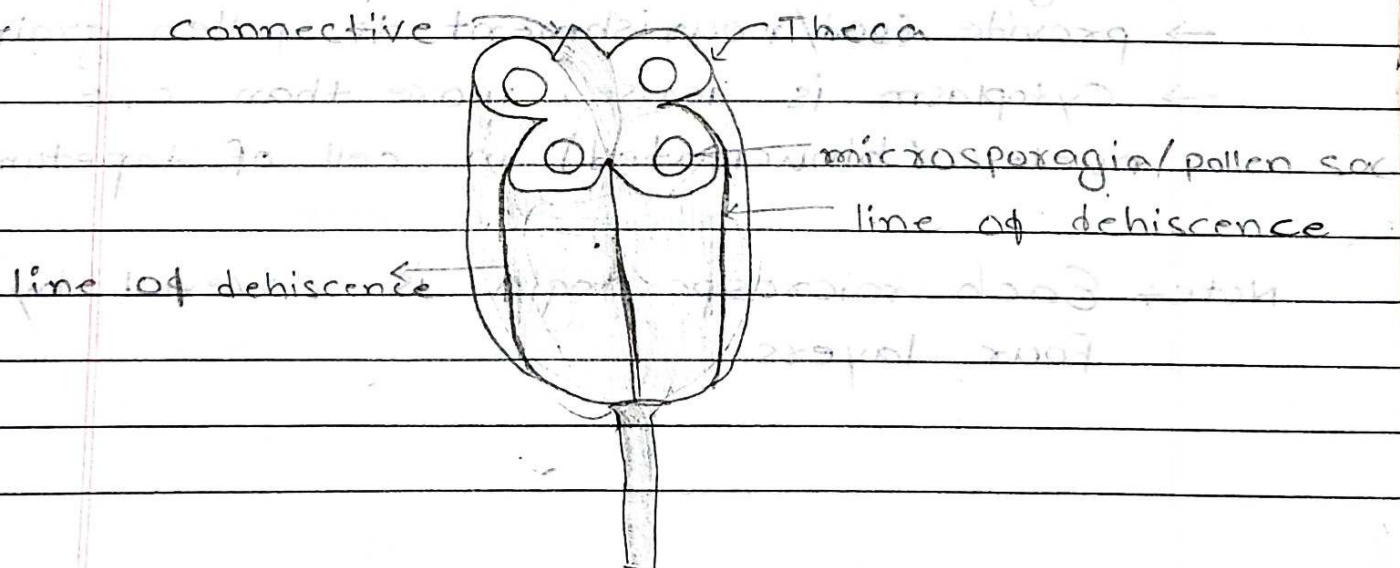


- Number and length of stamen vary in flower of different species.

* Anther



- In each lobe two circular structure are present called microsporangia. So total no. of microsporangia in anther is four.
- Anther is tetragonal or tetrasporangia
- Anther is very clear/distinct in T.S.
- Microsporangia is placed longitudinally
- Anther is called dithecal because each lobe has two theca.
- Two theca are separated by longitudinal groove (depression) / line of dehiscence (Region where anther burst)

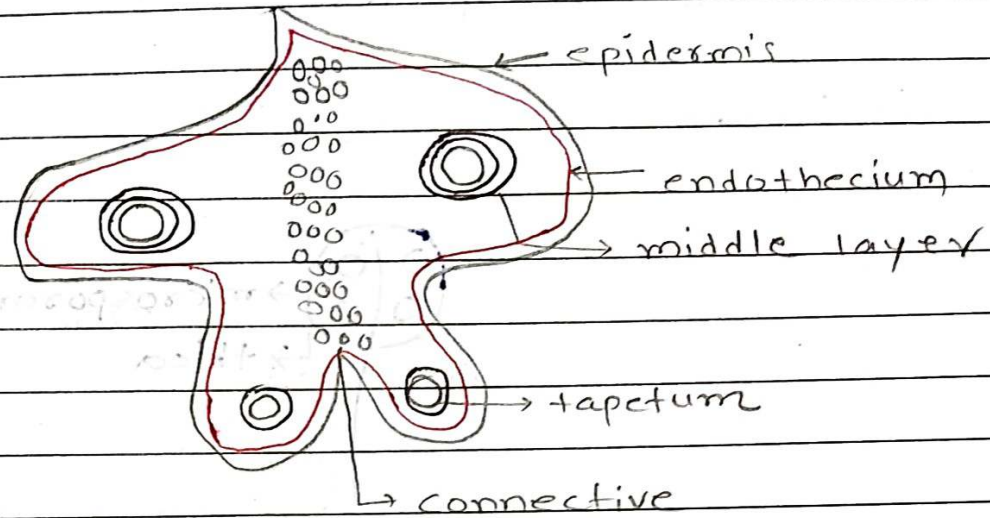




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* Structure of microsporangia



• Epidermis
→ Outer layer, single

• Endothecium
→ Single layer

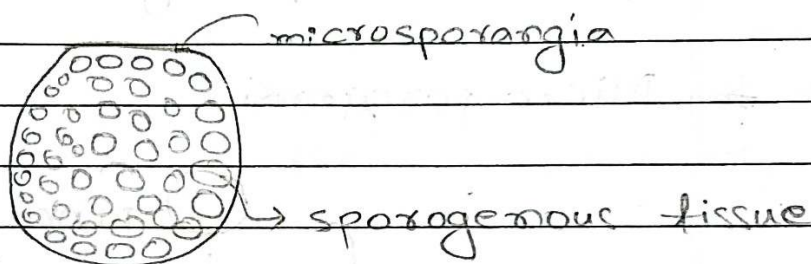
• Middle layer
→ 1-3 layer

• Tapetum
→ Single, innermost layer or microspore
→ provide food/nourishment to pollen grain
→ Cytoplasm is dense, more than one nucleus (binucleated) in cell of tapetum.

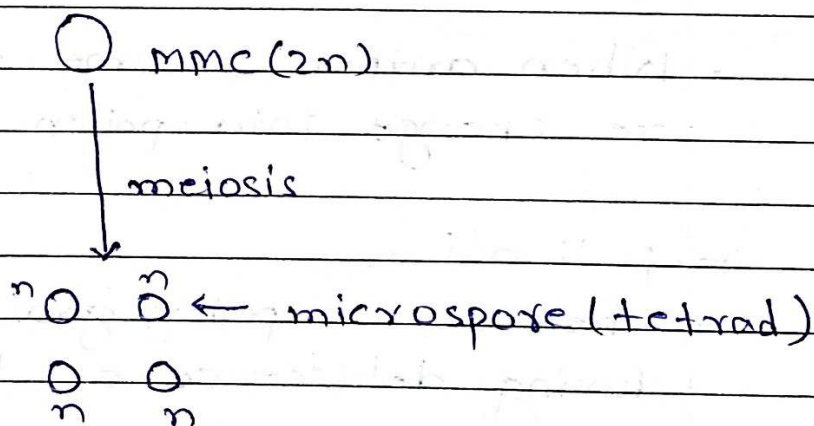
Note: Each microsporangia is covered by four layers



- Epidermis, endothecium and middle layer help in protection and dehiscence of anther.
- Connective - Each lobe is separated by sterile tissue.



- Each microsporangium consists of a group of homogeneous cells called sporogenous tissue.
- Each cell of sporogenous tissue is called microspore mother cell (MMC) or pollen grain mother cell (PMC).

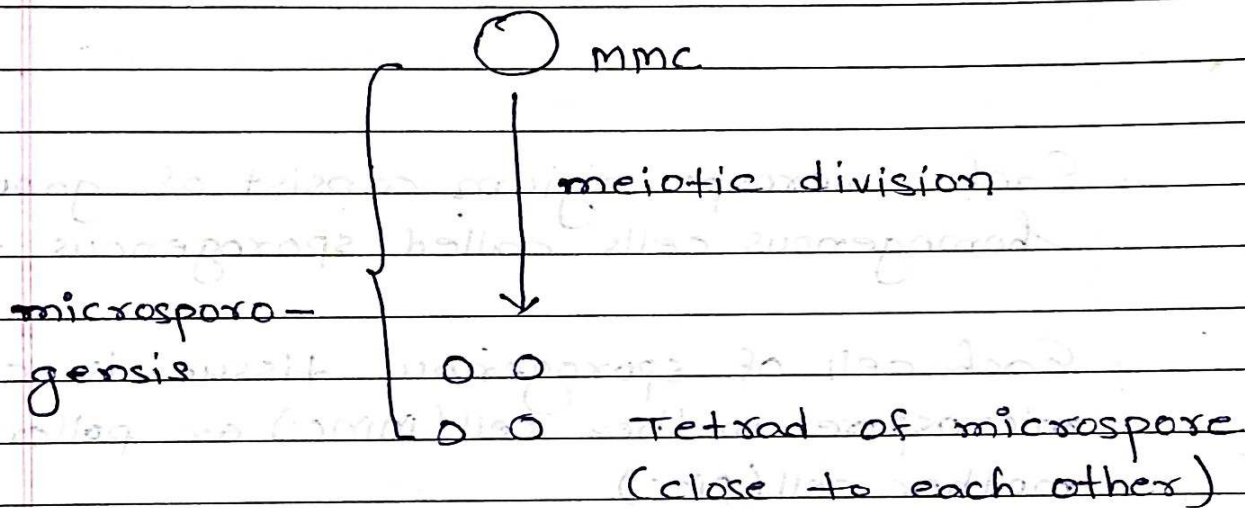


- Each MMC/PMC undergoes meiosis division and forms four haploid microspores or pollen-grains.



- Microsporogenesis = Formation of microspore from MMC is called microsporogenesis.
- After formation of pollen grain or microspore microsporangia is called pollen sac.

* Microsporogenesis



- When anther become mature/old microspore change into pollen grain.

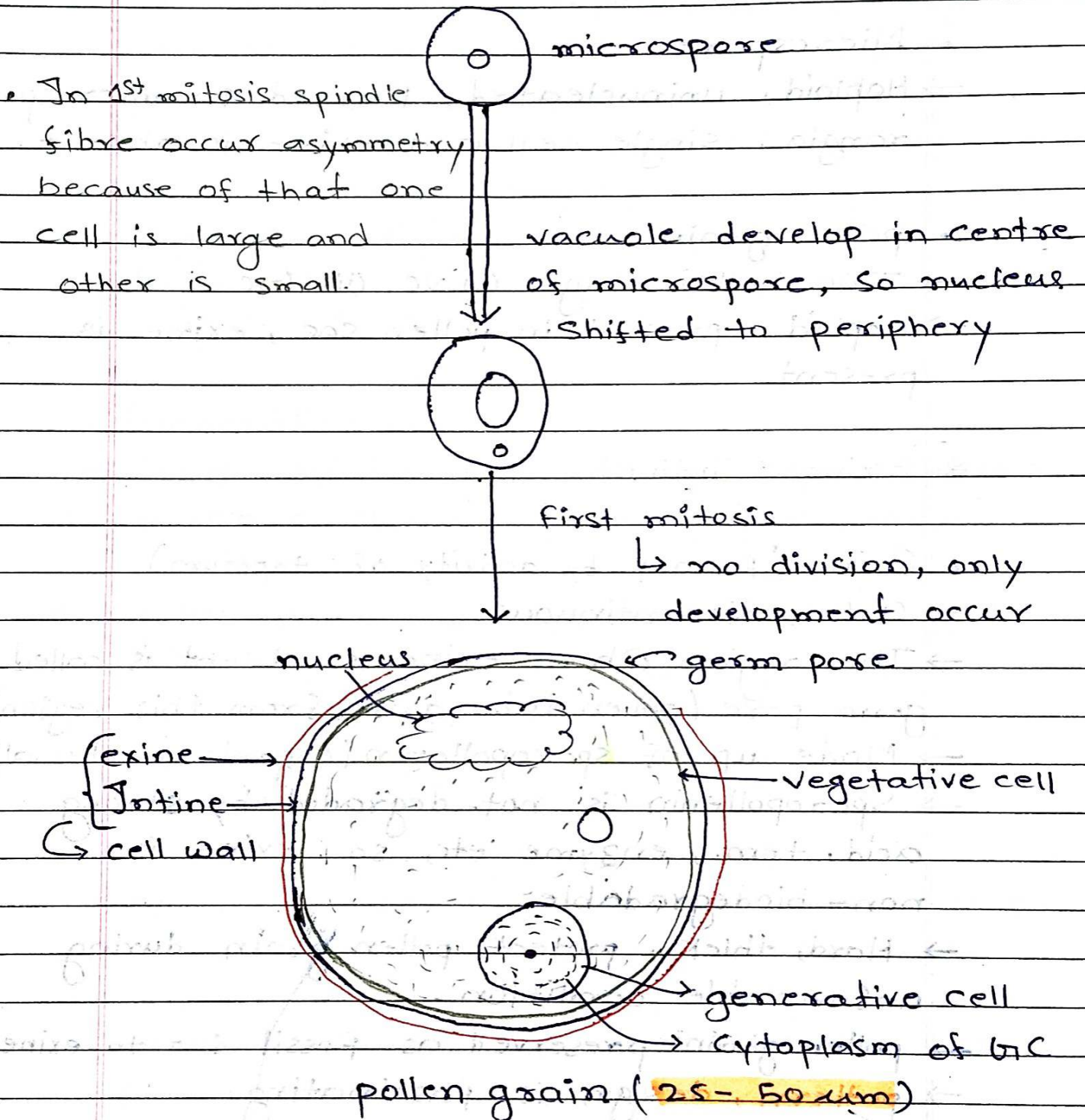
* pollination

X → Release of pollen grain from anther during dehiscence or breaking of anther.

- Transfer of pollen from anther to stigma is called pollination.



* formation of pollen grain



- Exine $\rightarrow$ outer layer, incomplete
- Vegetative cell $\rightarrow$ N, large and irregular
↳ nucleus
- Generative cell $\rightarrow$ N, small, floats in cytoplasm of VC.



* Microspore & pollen grain

• Microspore

→ Haploid, uninucleated, formed in microsporangia, single cell and exine is absent

• pollen grain

→ Two celled stage (i) VC (ii) GC

→ Haploid, present in pollen sac, exine is present.

* Exine & Intine

• Exine (formed by activity of tapetum)

→ Outer, discontinuous.

→ The region where exine is absent is called germ pore (pollen tube arise from this region)

→ Made up of **sporopollenin** (organic material)

→ Sporopollenin is not degraded by strong acid, tem., enzyme etc, so exine is non-biodegradable.

→ Hard, thick, protect pollen grain during unfavorable condition.

→ pollen grain preserved as fossil due to exine.

→ pattern, design is fascinating.

• Intine

→ inner continuous layer

→ Made up of **pectin and cellulose**



Note: No., colour, shape and pattern of pollen grain vary in different plant.

* Vegetative and ~~term~~ generative cell

- Vegetative cell (N)
 - large cell, irregular nucleus
 - stored abundant food.
- Generative cell (N)
 - Small, spindle shape, float in cytoplasm of vc
 - Dense cytoplasm, prominent nucleus

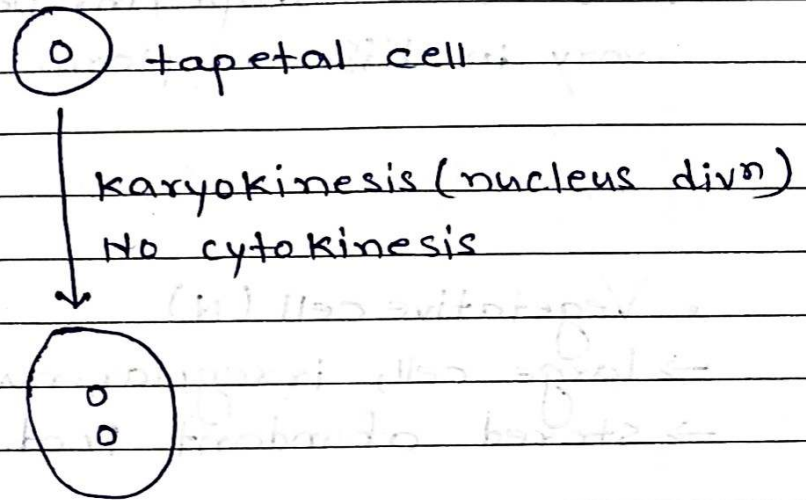
note: pollen grain represent male gametophyte because it form male gamete (GC)

* ~~if~~ ~~spore~~ ~~pollen~~ ~~grain~~ ~~to~~ ~~pollen~~ ~~grain~~

- Haploid
 - gamete, microspore, VC, GC and pollen grain
- Diploid
 - MMC/PMC, endothecium, epidermis, middle layer and tapetum.



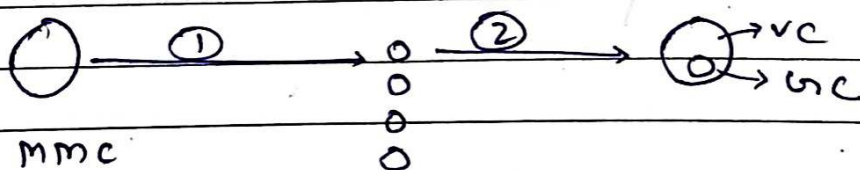
Q. How tapetal cell is binucleated?



Q. Why tapetal cell is binucleated?
→ for rapid pollen/microspore development.

- * 60% angiosperm plant release pollen grain from anther at two celled stage (i) vc (ii) uc

Q. No. of meiotic & mitotic division require for formation of mature pollen/two cell stage pollen

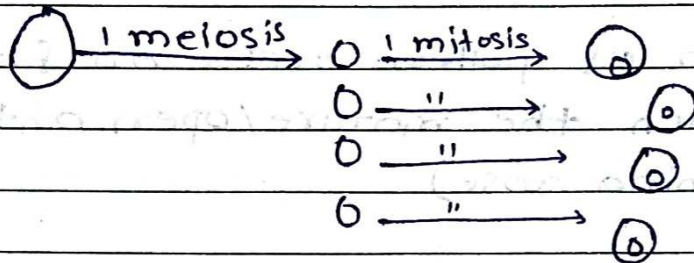


① → meiotic ② → mitotic

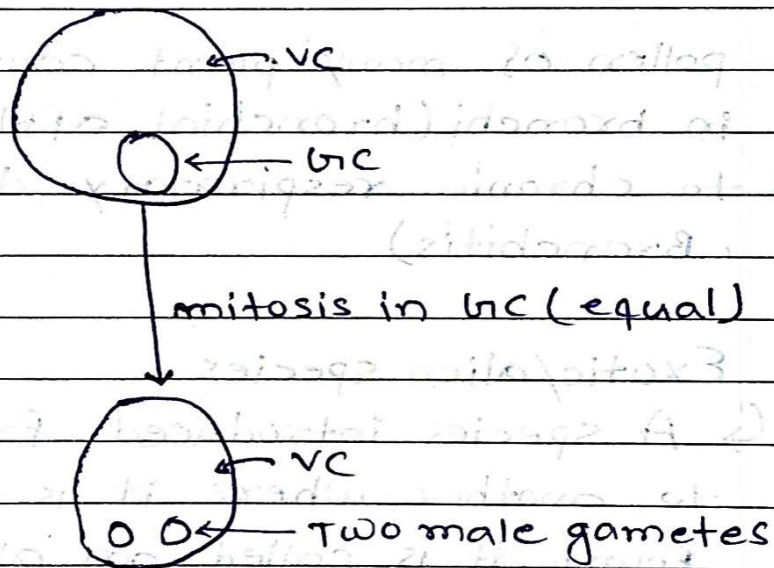


Q. No. of meiosis and mitosis division require for formation of 4 pollen grain?

→ 1 meiosis, 4 mitosis



• 40% flowering plant release pollen grain from anther at 3-celled stage.



• GC undergoes mitosis division and form two male gamete (both are equal)

Q. No. of meiosis and mitosis division for formation of one 3-celled pollen?

→ 1 meiosis and 2 mitosis



Q. No. of meiosis and mitosis for formation of four 3-celled pollen?

→ 1 meiosis, 8 mitosis.

note: Deposition of pollen occur on fingure, if you touch the mature/open anther of Hibiscus (china rose)

• pollen of Hibiscus is yellow in colour.

* pollen allergy

• pollen of many plant cause allergy, mainly in bronchi (bronchial afflictions) and. It lead to chronic respiratory disorder (Asthama, Bronchitis)

• Exotic/alien species.

↳ A species introduced from one country to another where it is not naturally found. It is called an alien or exotic species.

I ex: Parthenium/carrot grass came in India along with wheat and spread all over India (ubiquitous) and it cause allergy.



* pollen food

- pollen is rich in nutrient and used as food and also available in market in syrups and tablets in Western countries.
- pollen increase performance of athletes and race horse.

* pollen viability

- Time period in which pollen retain the ability to germinate on stigma.
- vary in different plant.

I. pollen viability of different plant

- (i) Cereals (wheat, rice) $\rightarrow$ 30 minutes
 - (ii) Rosaceae, solanaceae, leguminosae $\div$ several months
- pollen viability depends on tem and humidity

* pollen bank

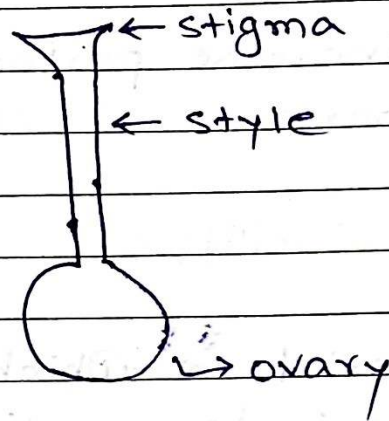
I. Storage of pollen at low tem. (-196°C) in N_2 liquid is called **cryopreservation**

- pollen bank is similar to seed bank
- pollen used in crop breeding program/research lab.



* Gynocium

- female reproductive organ of angiosperm
- unit $\div$ pistil
- pistil consist of three parts



- (1) Stigma $\div$ Landing platform for pollen grain
- (2) Style $\div$ Slender, connect stigma and ovary
- (3) Ovary $\div$ Basal, swollen part

I. If there is only one pistil present in a flower, it is called monocarpellary.
ex $\div$ Hibiscus ?

I. If there are more than one pistil present in a flower, it is called multicarpellary or polycarpellary.



R.

polycarpellary

Syncarpous

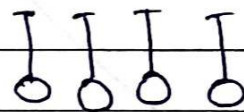
→ all pistils are fused



eg. papaver, mustard
and tomato Hibiscus

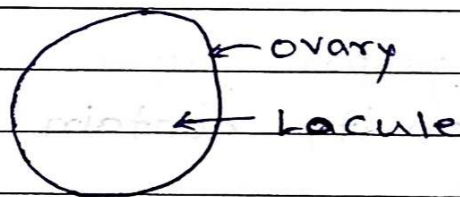
Apocarpous

→ all pistils are free.



eg. michelia, lotus &
rose, champa

* Ovarian cavity (Locule)

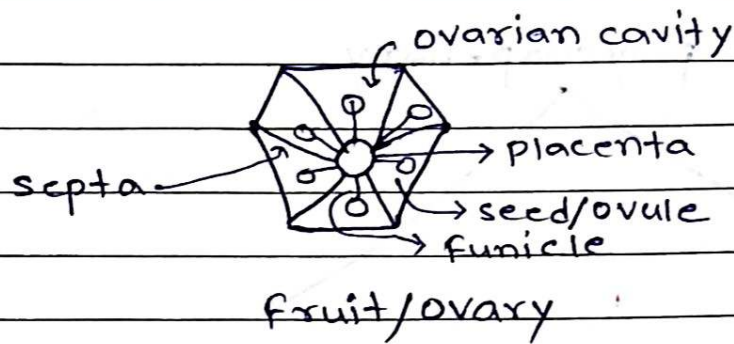


- The ovary which has more than one ovarian cavity is called multilocular.
- An ovary contains: Ovarian cavity, ovule, placenta and funicle (stalk)
- Ovarian cavity ÷ one or more in number (separated by septa)
- Ovule is attached to placenta through a stalk called funicle.



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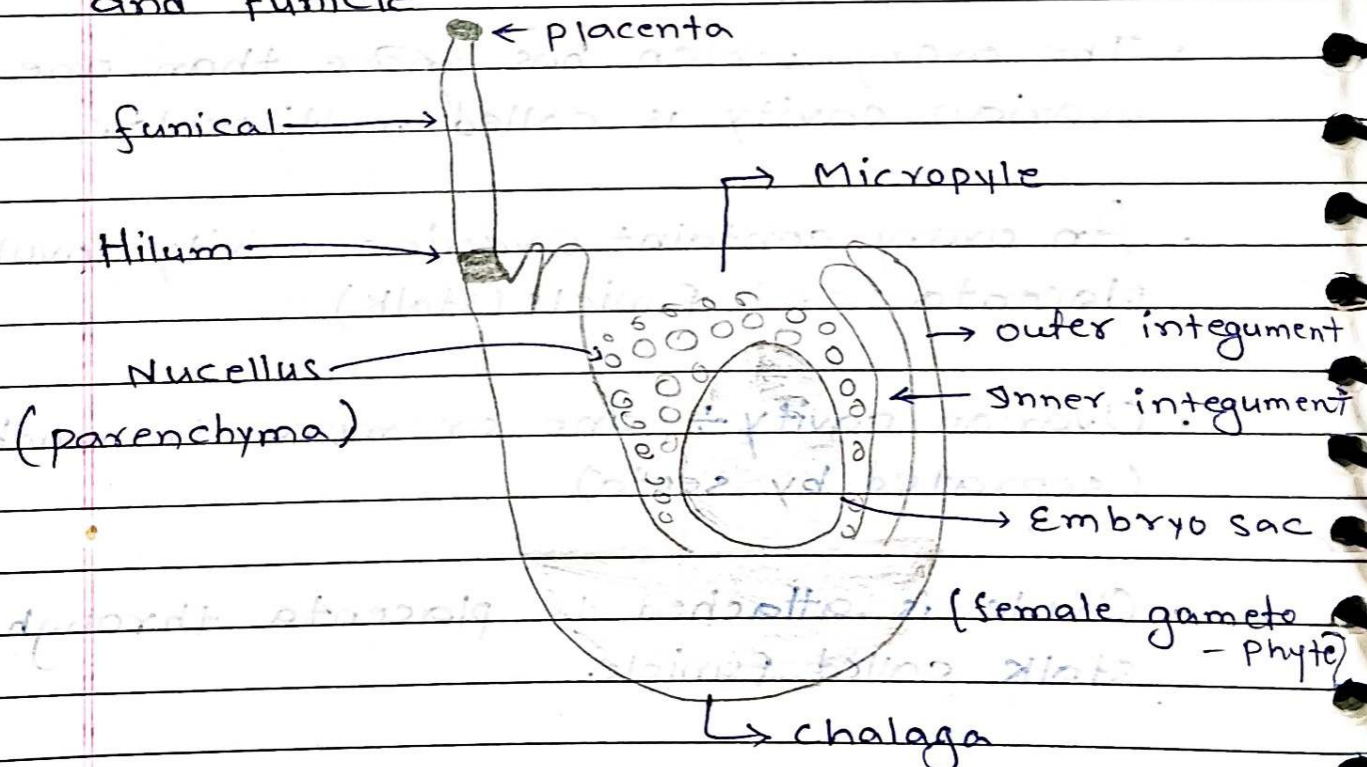
Ovule

Single ovule
ex: wheat, mango,
paddy

many ovule
ex: watermelon,
papaya, orchid

* Ovule/Megasporangium

→ Ovarian cavity contain ovule, placenta and funicle





- Funicle ÷ Body of ovule is attach to placenta by funicle.
- Chalaza ÷ Basal part of ovule
- Integument ÷ Nucellus ($2N$) covered by one or two protective covering/covering of ovule call integument.
- Micropyle ÷ Tip of ovule where integument are absent
- Nucellus ÷ food store, $2N$
- Hilum ÷ Common attachment of ovule and funicle.
or, The body of the ovule fuses with funicle in the region called hilum. Thus hilum represent junction b/w ovule and funicle.
- Embryosac ÷ Usually one embryosac inside ovule formed from megaspore.

Note: In 80% of angiosperm plant **anatropous ovule** is present. In anatropous ovule micropyle & chalaza lie in straight line and micropyle & funicle are placed side by side.

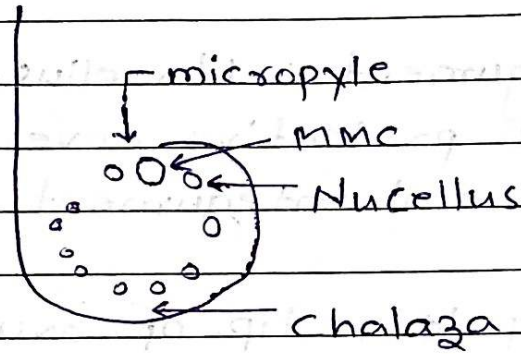


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* Megasporogenesis

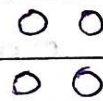
formation of megaspore from megaspore mother cell is called megasporogenesis.



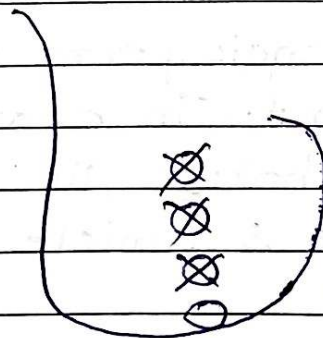
- The large nucellus cell present at micropyle side is called MMC (megaspore mother cell) which has dense cytoplasm and prominent nucleus.

MMC

meiosis / reductional division



four megaspore (N)



3 megaspore will degenerate and one megaspore live (present at chalazal end) is called functional megaspore.



- A functional megaspore form one embryo-
sac or ^{female} gametophyte

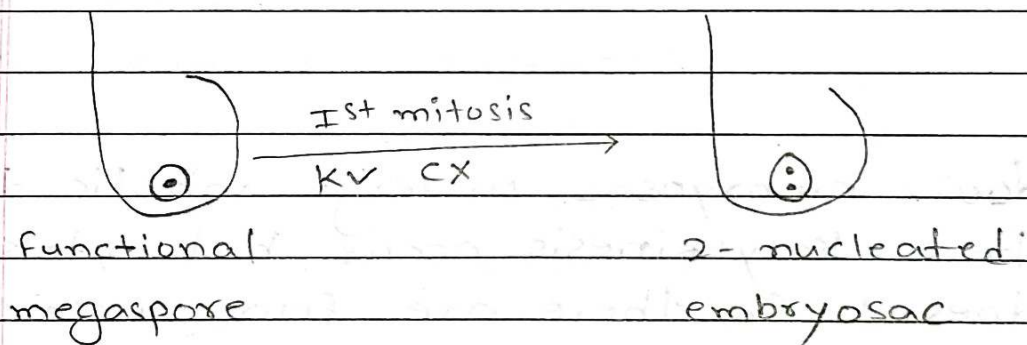
Q. If there are 40 MMC in ovule then no. of functional megaspore will be?

→ 40

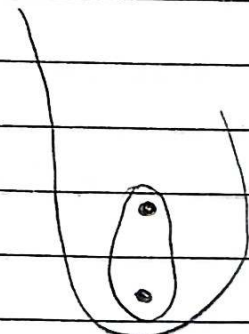
Q. No. of meiosis required to form 100 embryo-
sac?

→ 100 meiosis

* formation of embryo sac

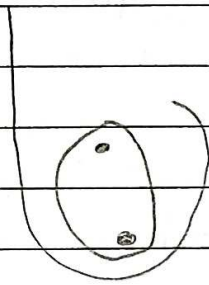


Both nucleus move
toward opposite
pole



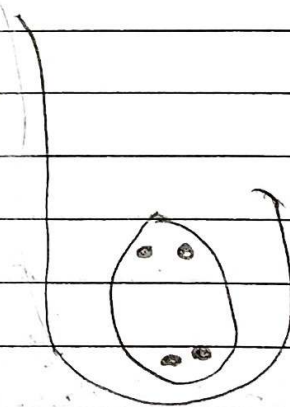


- In 1st mitosis division in megaspore, karyokinesis occur but cytokinesis doesn't. After mitosis/mitotic megaspore converted into embryosac, which is binucleated.
- Both nucleus of embryosac moves toward opposite pole.



Binucleated embryosac

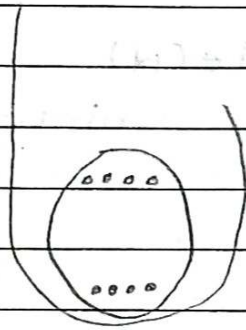
Now, embryosac undergo mitotic div'n (2nd) here karyokinesis occur but cytokinesis doesn't. So there are four nuclei in one embryosac.



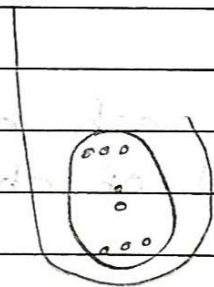
4-nucleated embryosac



Again embryosac undergo mitotic div (3rd)
here again karyokinesis occur but cytokinesis
doesn't. So now embryosac is 8-nucleated.



One nucleus from each pole move toward
centre



cytokinesis (cell wall form)

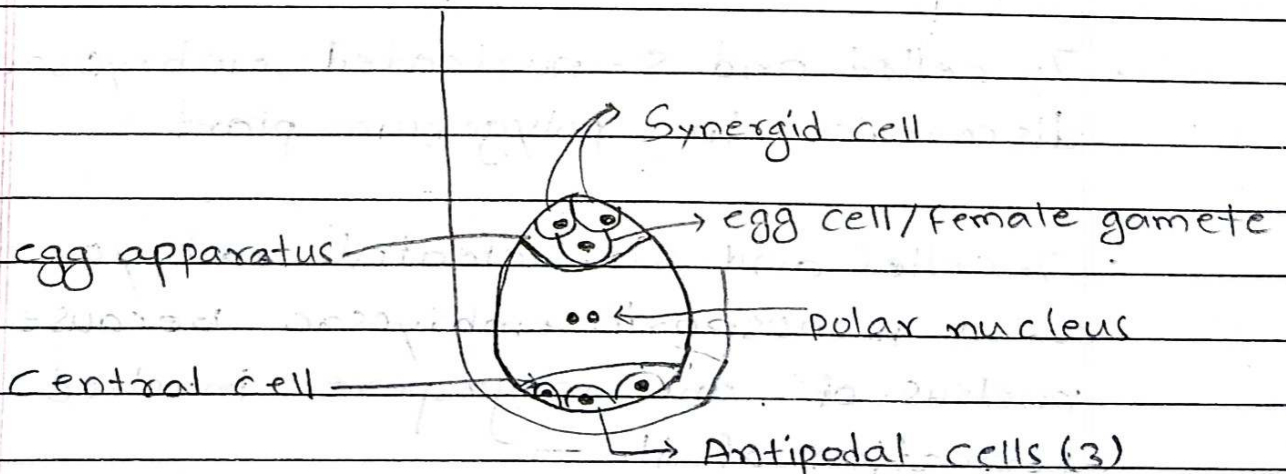
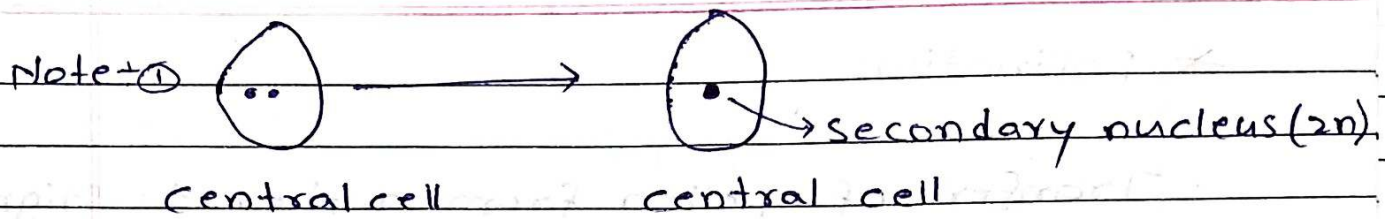


Fig: 7-celled and 8-nucleated embryosac



- Synerid cell
 - Two in number, each have one nucleus
 - Near micropyle end.
- egg / female gamete (N)
 - One in number, uninucleated, near micropyle end.
- Central cell
 - One in no., binucleated
 - Nucleus of this cell is called polar nucleus
- Antipodal cell
 - Three in no., each has one nucleus present at end of chalaza
- Finally embryo sac become 7-celled and 8-nucleated structure.
- 7-celled and 8-nucleated embryo sac found in max^m angiosperm plant (80%).
- 7-celled and 8-nucleated embryo sac first discovered in polygonum plant.
- 7-celled and 8-nucleated embryo sac also called monosporic embryo sac because single nucleus of one megaspore involved in formation of it.

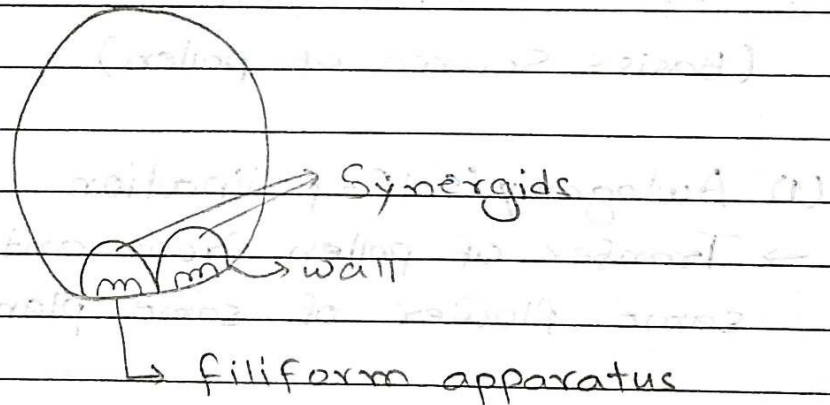


Both polar nucleus fused and form secondary nucleus.

(ii) To ensure formation of haploid female gamete MMC undergo meiosis division.

(iii) Central cell or polar nucleus is below the egg apparatus or egg/female gamete.

- Filiform apparatus



→ Wall of synergid form special thickening/structure called filiform apparatus and this apparatus secrete chemical that guide pollen tube into embryo sac (synergid)

* Pollination

- Transfer of pollen from anther to stigma is called pollination (may not same species)
- Male gamete present in pollen grain and female gamete present in embryo sac
- Both male and female gametes are non-motile.
- To achieve fertilisation of δ & ♀ gamete pollination is required.

* Types of pollination (Basis $\pm$ Source of pollen)

(1) Autogamy/self-pollination

- Transfer of pollen from anther to stigma of same flower of same plant.
- In open flower autogamy is less common.
- In close flower only autogamy occur.

Note $\div$ Autogamy in open flower is possible when both mature at same time (stamen & pistil) and both are close to each other



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- In viola (common pansy), oxalis and commelina, there are two types of flower

(A) Cleistogamous

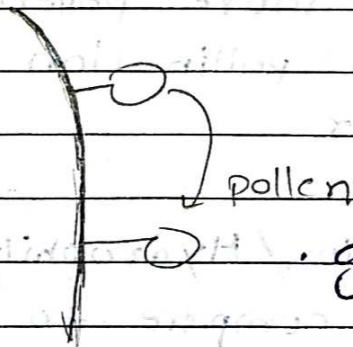
- closed flower
- near/in ground
- assure seed formation in the ^{absence} ~~absent~~ of pollinator
- Due to continue selfing/autogamy, it lost some characters.
- Inbreeding depression (least variation) occur.

(B) Chastogamous

- open flower
- Autogamy/cross pollination
- present at aerial

(2) Geitonogamy

- Transfer of pollen from one flower to stigma of another flower of same plant.



genitically : autogamy

functionally : cross-polln.

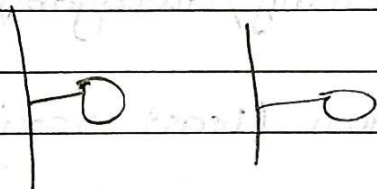


• Geitonogamy is not a true cross pollination.

(3) Xenogamy

→ Transfer of pollen from anther of one plant to stigma of another plant.

• Functionally/genitically cross pollination.



→ Agent of pollination

Abiotic

Biotic

(1) Abiotic (non-living)

→ less common

→ pollinated with the help of wind, water

→ plant produce more pollen because in wind or water pollination maximum lost of pollen occur.

• Water pollination/Hydrophily

→ Less common compare to anemophily

→ limited to 30 genera, mostly monocots

• Ornithophily → pollination by birds.

• Entomophily → "

" insects.

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→ Movement of gametes in lower plant (algae, bryophyte, pteridophyte) happen with the help of H_2O and depend of H_2O for fertilisation. So distribution is limited.

→ Not all aquatic plant pollinated by H_2O for eg. water hyacinth and water lily flowers comes on surface of H_2O , then pollinated by wind or insects.

• Wind pollination / Anemophily

→ pollinated by wind

→ pollen is dry, light and non-sticky

→ Stamen is well exposed in air

→ Stigma is hairy & feathery to trap pollen

→ Tassel (eg: in maize, corn) represent stigma and style, it trap pollen.

→ One ovule present in one ovary

→ Numerous flowers packed in inflorescence to increase chance of pollination

→ Wind pollination is most common in grass.

* Types of hydrophily

(1) Epiphytely

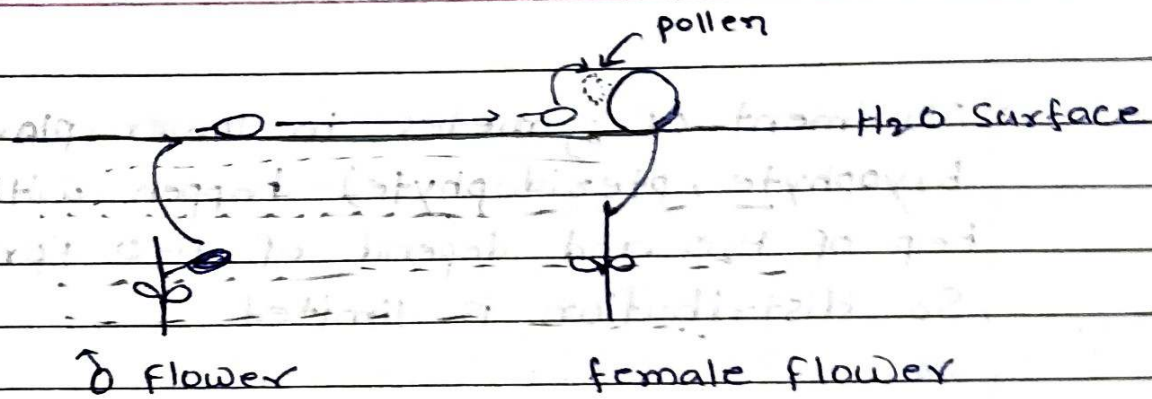
→ pollination on surface of H_2O

eg: in hydrilla & Vallisneria (fresh water)



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Vallisneria

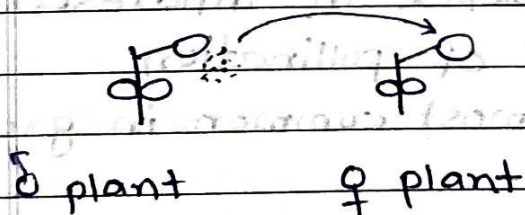
• Vallisneria is dioecious plant ($\rightarrow$ δ and ϕ flower on diff. plant)

• Male flower breaks and floats on surface of H_2O and release pollen.

• pollen reach to stigma

• The movement of male flower is passive.

(2) Hypohydrophily



• Both plant are inside H_2O

• pollen release inside water and it reach to stigma

• pollen is long, ribbon shape covered by mucilage (prevent from wetting)

eg: Zostera or sea grass (marine plant)



Note:- Water or air pollinated flower usually do not have fragrance, bright color and large size.

* Zoophily

- pollination by animals
- Small animals:- flies, beetles, wasp, moth, ants, honey bees, butterfly, sun bird,
- large animals:- Lemus (primates), arborea (tree dwelling rodents), garden and gecko lizard.
- foul odoured plant pollinated by flies & beetles
- flower usually large, colored, attractive and have fragrance.
- Nectar and pollen:- two common rewards.
- pollen grain:- sticky covered by oily layer (pollen kit)
- Amorphophallus is tallest flower (6 feet), it is safe to lay eggs.



- In majority of plant pollination done by honey bees.
- In particular plant ~~pollen~~ pollination depend on particular animal (species specific)
- Moth (animal) lay its eggs in flower of yucca, larva gets food by consuming seed from yucca. Moth help in pollination of yucca. This relationship is mendatory

Note: If flowers are small, then they are clustered to attract insects.

* Outbreeding devices

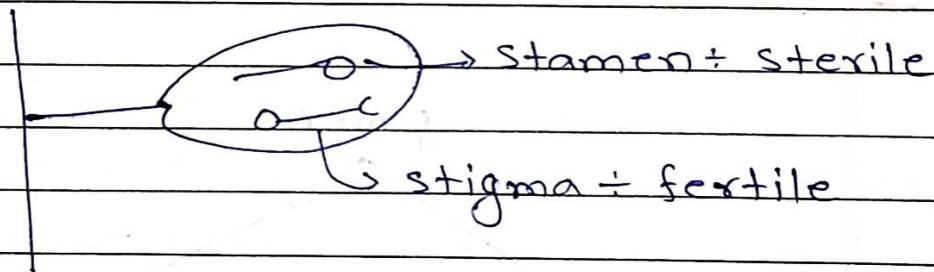
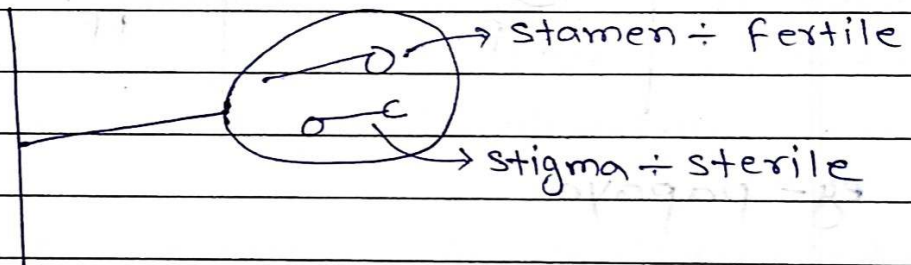
- Flowering plants have developed many devices to discourage self pollination & to encourage cross pollination.
- Outbreeding in bisexual/Hermaphrodite flower.
 - In most of plant flower are bisexual and it ~~produce~~ promote self-pollination (homozygosity) but it lead to inbreeding depression.



(i) If anther is mature but stigma is not receptive & vice versa (Dichogamy)

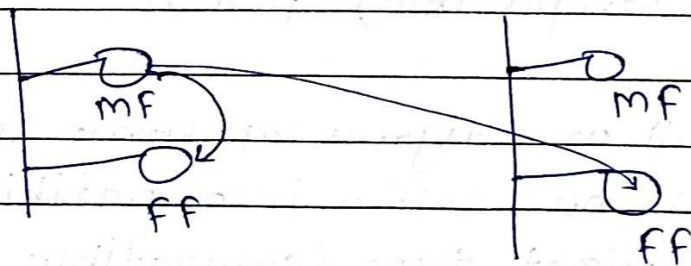
(ii) Stamen and pistil are far away from each other in same flower (Herkogamy)

(iii) Self incompatibility/self sterility
→ Control by genes.



• Outbreeding in monoecious

→ Male and female flower on same plant



→ Autogamy X, geitonogamy ✓, Xenogamy ✓



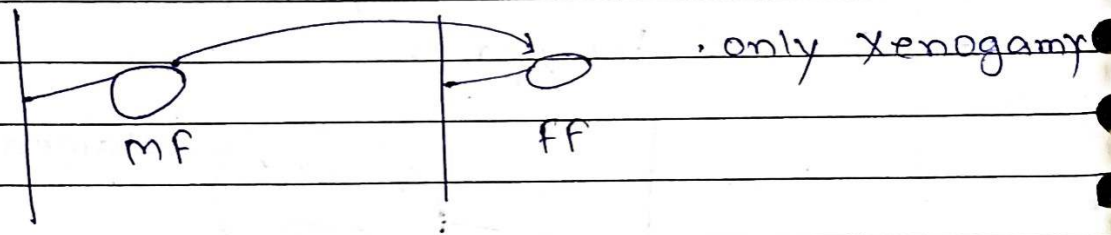
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eg- Maize, castor

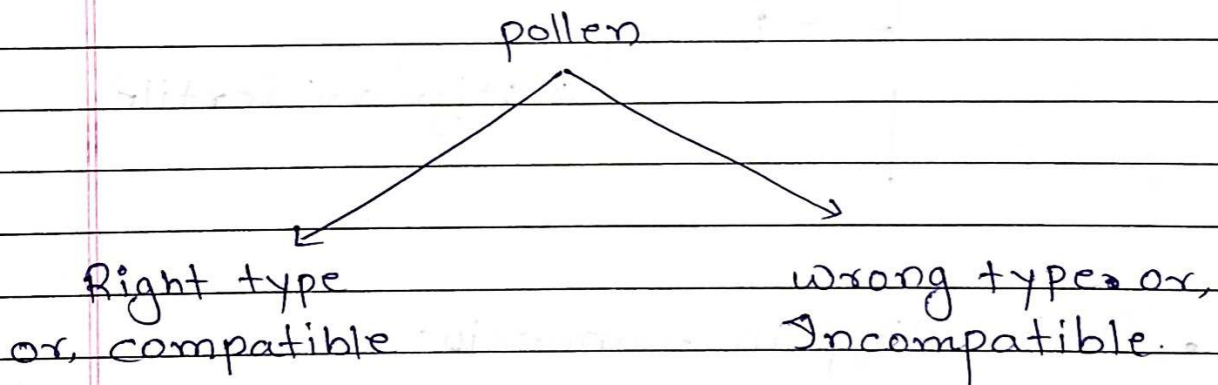
• Outbreeding in dioecious

→ Dioecious plant always promote outbreeding because both male and female flowers are present on different plant.



eg- papaya

* pollen-pistil interaction



(1) Right type (compatible) pollen

→ If pollen fall on stigma of same species and there is no self-incompatibility then it is called right type/compatible pollen.



(2) Wrong type/incompatible pollen

→ If pollen fall on stigma of different species or on same species but there is self-incompatibility then it is called wrong type pollen.

- first event of pollen-pistil interaction is recognition of compatible pollen. If pollen is incompatible then pistil reject the pollen, if pollen is compatible then pistil accept the pollen and promote post-pollination events that lead to fertilisation.
- pistil secrete chemical to recognise the pollen, whether it is compatible or incompatible.
- pollen-pistil interaction is a chemical and dynamic process.
- When pollen is accepted by pistil then pollen form pollen tube (extension of vc) and enters into stigma. If pollen is at 2-celled stage then vc cell undergo mitosis divⁿ and form 2 male gametes. If pollen is already at 3-celled stage then there is no need of mitosis divⁿ at the time of pollen tube formation, because it already had two male gametes.



- pollen tube enters into ovary through style. There are three ways for pollen tube to enter into ovule (i) through chalazal (ii) through integument (iii) through micropyle
- Micropyle is only way through which pollen tube can enter into embryo sac
- In embryo sac pollen tube enters into one synergid cell and releases their content (two male gametes)
- One male gamete fertilises with egg and forms zygote ($2n$), this fertilisation is called syngamy.
- Another male gamete fertilises the central cell and forms primary endosperm cell ($3n$), this fertilisation is called triple fusion.
- Now zygote forms (converts) into embryo ($2n$) and primary endosperm forms endosperm, this is called post-fertilisation
- Endosperm provides nutrients to embryo-sac



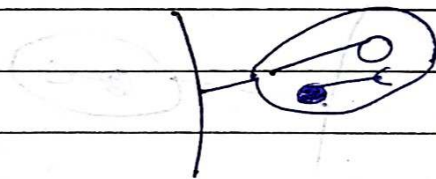
- The events from deposition of pollen on stigma, until pollen tube enters into ovule is called pollen-pistil interaction.
- Transmitting tissue is present in style, pollen tube pass through these tissues.

Note:- 3 antipodal cell and one synergid cell degenerate after some time

Note:- Breeders identify chemical which help in pollen-pistil interaction & trying to do pollination in non-compatible species.

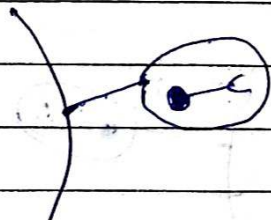
Note:- pollination doesn't guarantee the transfer of the right type of pollen.

* Artificial hybridisation



bisexual flower

Removal of stamen (anther) in young stage/flower is called Emasculation (bisexual flower)

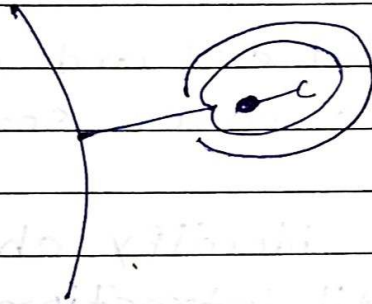




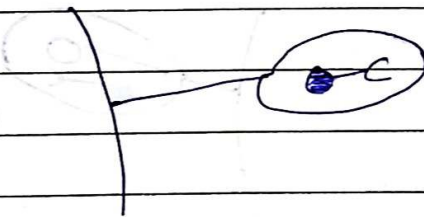
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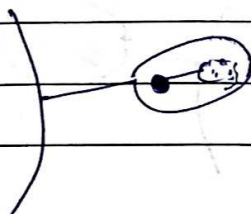
Flower covered by butter paper to prevent contamination from unwanted pollen, It is called bagging.



- Once stigma become receptive/attain maturity
- Removal of butter paper

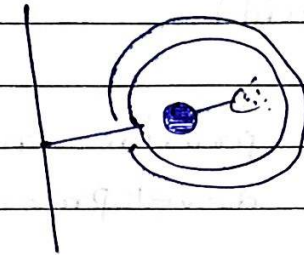


Dusting of desired pollen on stigma





Rebagging (until fruit formⁿ)



Note: Emasculation is not required in unisexual flower in female parent

* In-vitro pollen germination

- When we add 10% sugar solⁿ on Pollen (pea, chick pea, vinca, balsam etc) then pollen tube form, this is called in-vitro pollen germination.

* post-fertilisation

↳ Zygote → Embryo
↳ primary endosperm → Endosperm
↳ Ovule → seed
↳ ovary → fruit

• Types of Endosperm

Nuclear

cellular



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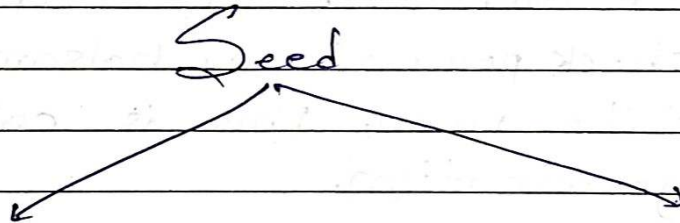
(1) Nuclear endosperm

→ In PEC many karyokinesis (free nuclear divn) occur and it convert into nuclear endosperm. At the end cytokinesis occur and nuclear endosperm convert into cellular endosperm.
eg Coconut (liquid)

Note: (i) Endosperm provide nutrition to embryo.
(ii) Endosperm development precedes embryo development.

(2) Cellular endosperm

→ Many division occur in PEC and it convert into cellular endosperm.
eg. White part (kernel) of coconut.



Non-endosperm seed
or Non-albuminous

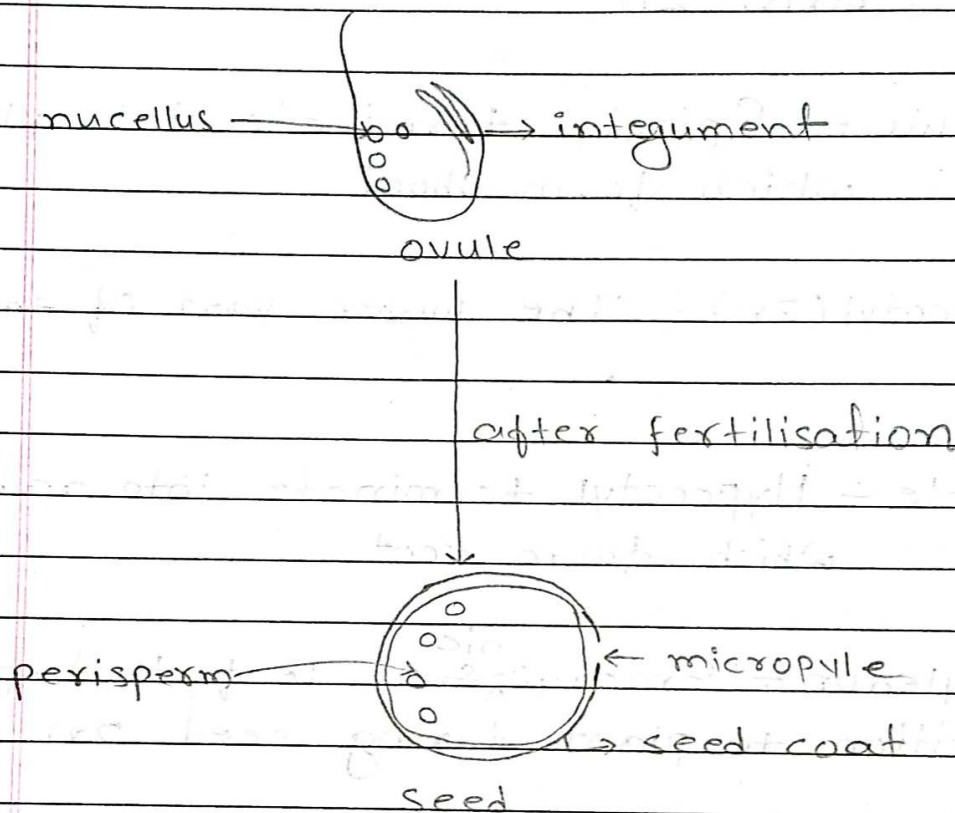
→ Embryo consume
Complete endosperm
during its development
→ in most of dicot
except castor

Endospermic seed or
Albuminous

→ Embryo consume some
portion of endosperm
during its development
→ in most of monocot
except orchid.

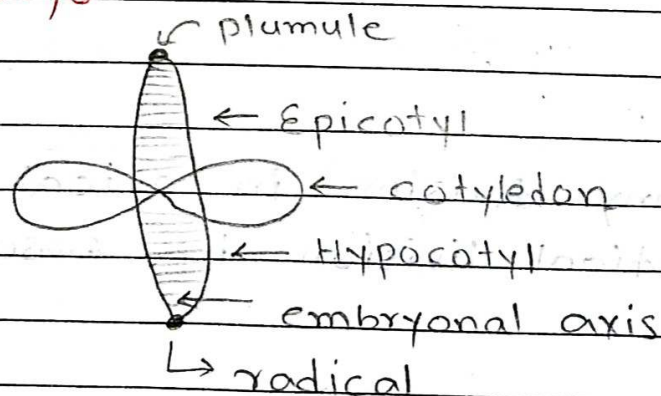


* Dicot seed



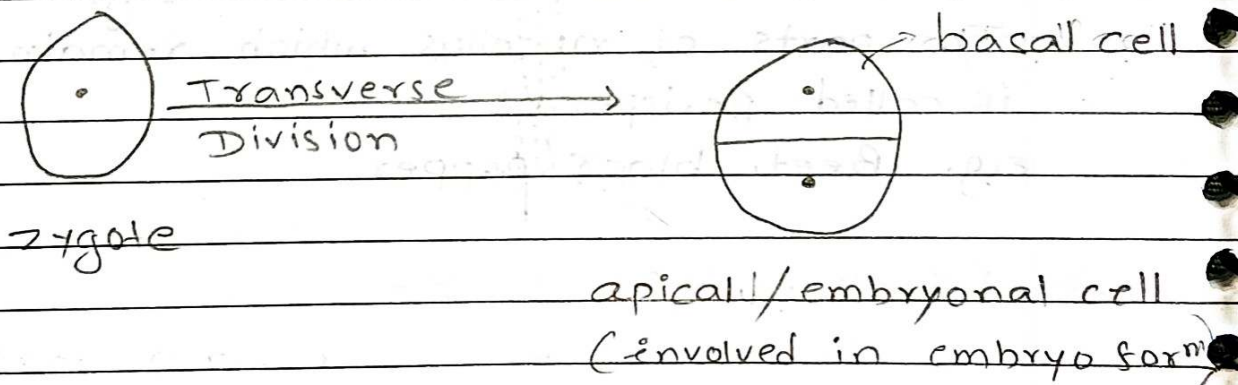
- H_2O , O_2 enter into seed through micropyle.
 - The parts of nucellus which remain in seed is called perisperm.
- e.g. Beet, black pepper

* Dicot embryo



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- Epicotyl $\div$ The upper part of embryonal axis, $2n$
- Plumule $\div$ Epicotyl terminate into plumule which form shoot
- Hypocotyl ($2n$) $\div$ The lower part of embryonal axis.
- Radicle $\div$ Hypocotyl terminate into radicle which form root.
- Cotyledon $\div$ Embryo^{nic} ~~see~~ leaf that provide nutrition to plant during seed, $2n$
- Zygote/embryo formed at micropylar end.

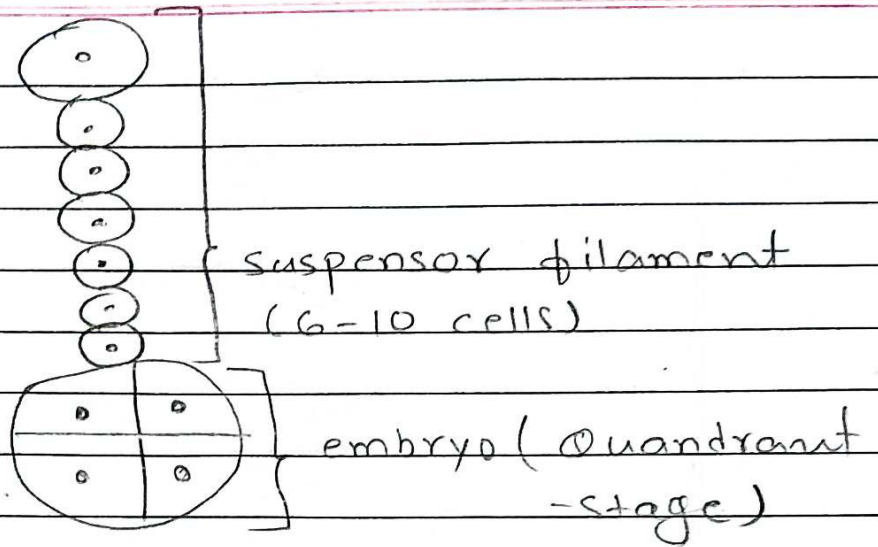


- Many division in ^{basal} ~~apical~~ cell and two vertical division in ~~basal~~ ^{apical} cell occur.

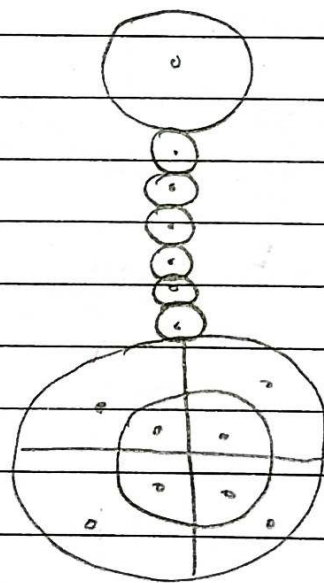


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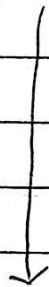


Quadrant stage embryo
undergo division



octant stage embryo

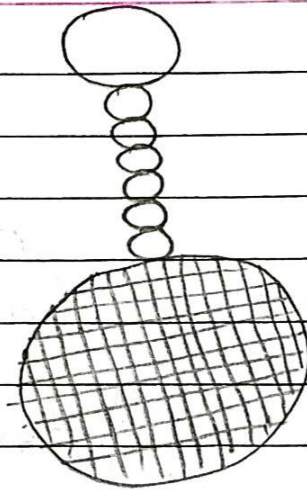
many division





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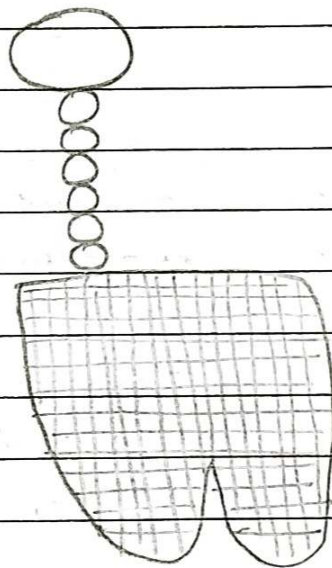
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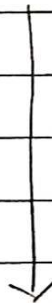
globular embryo

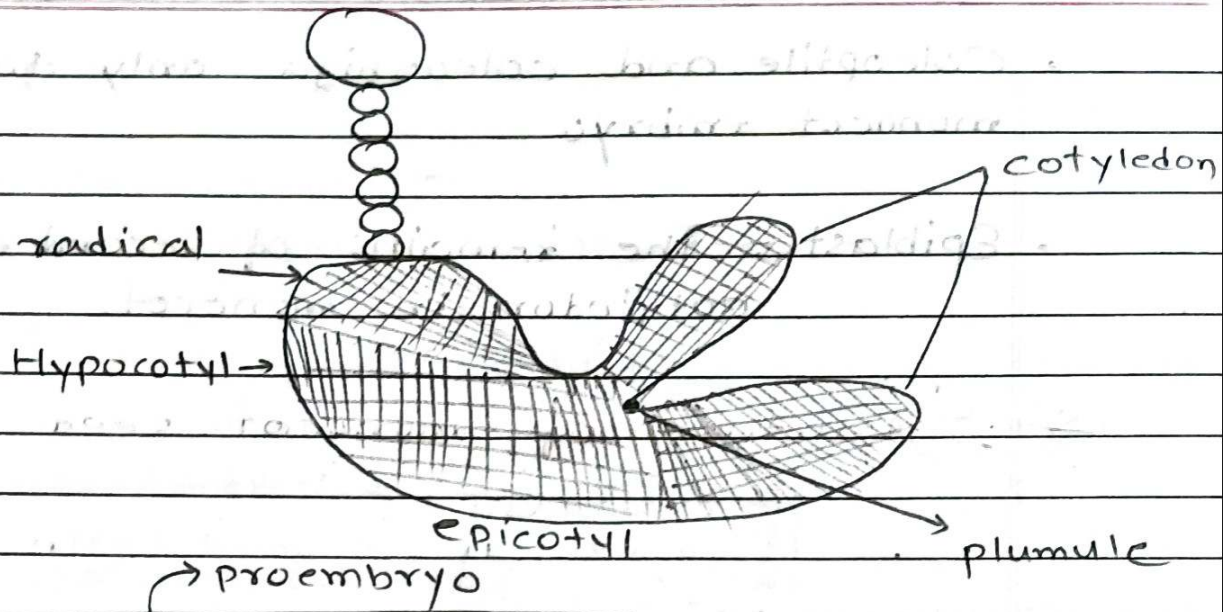


many division in globular embryo



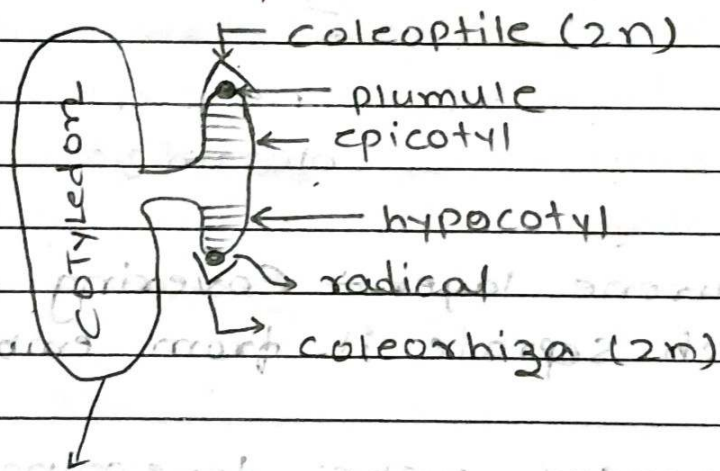
heart-shape embryo





- Quadrant $\rightarrow$ octant $\rightarrow$ globular $\rightarrow$ heart $\rightarrow$ mature embryo

* Monocot embryo



single, large shield shape cotyledon (Scutellum)

- Coleoptile $\div$ Covering of plumule
- Coleorhiza $\div$ Covering of radical



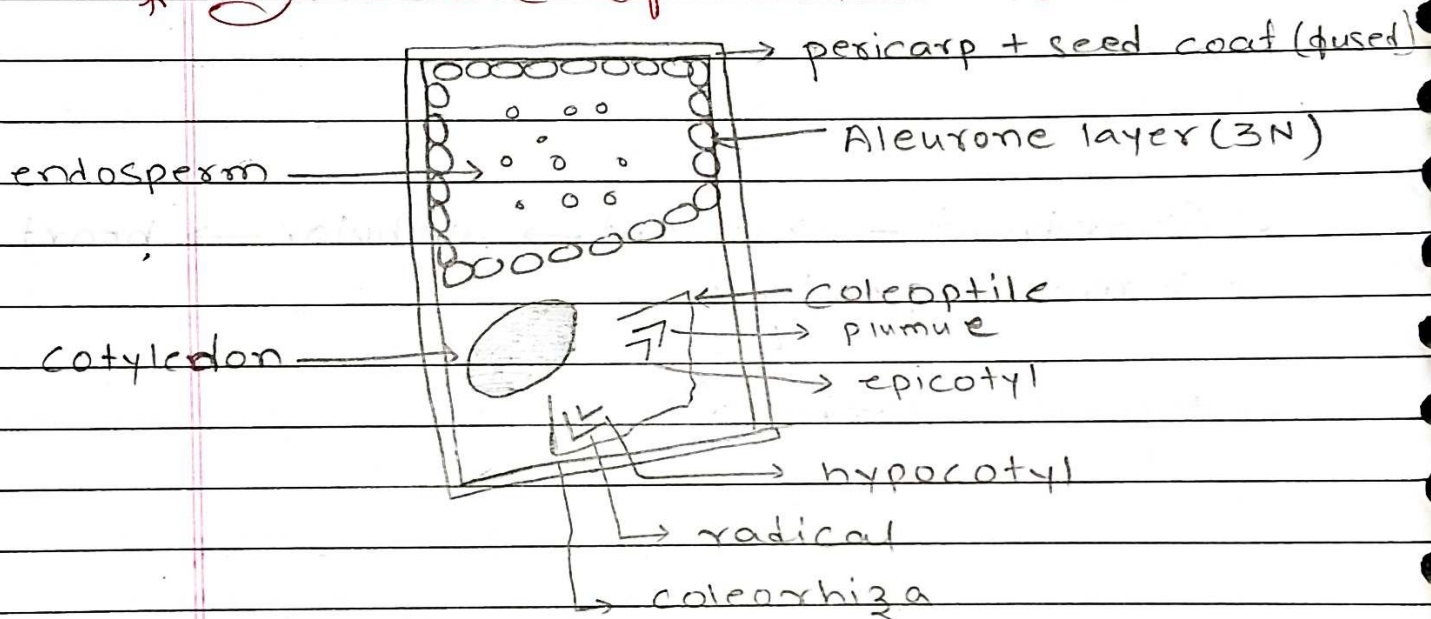
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- Coleoptile and coleorhiza only found in monocot embryo

- Epiblast ÷ The remains of second cotyledon in monocot.

* Structure of monocot seed.



- Aleurone layer ÷ Covering of endosperm which separate it from embryo.
- Suspensor pushes developing embryo toward endosperm.

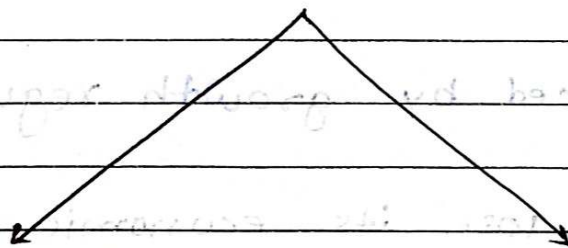


* Seed

- Ovule $\rightarrow$ seed
- Ovary $\rightarrow$ fruit } $\rightarrow$ Simultaneously
- Seed is final product of sexual reproduction
- Groundnut $\div$ Non-endospermic
- Barley $\div$ Endospermic
- parts of seed $\div$ embryonal axis, seed coat and cotyledon.
- When seed matures, its water content is reduced and seed become relatively dry (10-15 percent moisture by mass). The general metabolic activity of embryo slows down. The embryo may enters a state of inactivity called Dormancy.

* Types of fruit

Fruit



Dry fruit

$\rightarrow$ pericarp is not divided
e.g. Mustard, groundnut

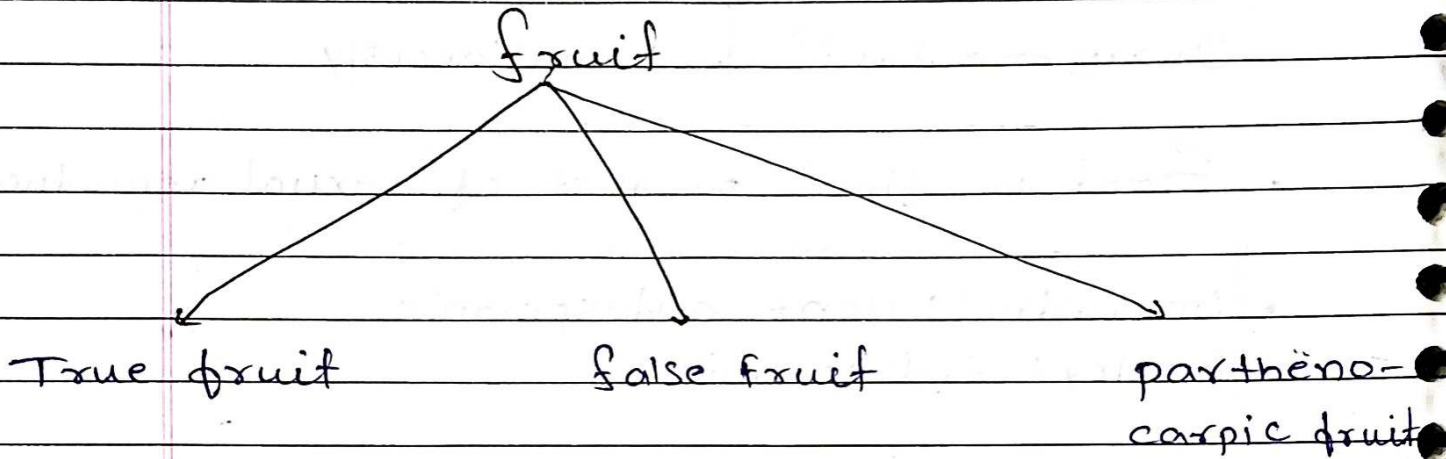
fleshy fruit

$\rightarrow$ pericarp is divided into
epicarp, mesocarp and
endocarp.

e.g. mango, Guava, orange



- Relation b/w seed and ovule.
(i) ovule = seed (ii) ovule > seed



- True fruit

- fruit formation from ovary
- ~~eg.~~ most of fruits are true fruit

- False fruit

- fruit formation from other than ovary
(like from thalamus)
- e.g. apple, cashew, strawberry

- Parthenocarpic fruit

- fruit formation without fertilisation
- seed absent
- e.g. Banana
- Can be induced by growth regulator.

Note: pomegranate lose its economic importance if made by parthenocarpy.



* Advantage of seed.

- Better dispersal method so seed transfer from one place to other
- Store food material, utilised ~~leaf~~ until leaf formed/ regain photosynthesis capacity
- Hard seed coat can protect young embryo.
- Product of sexual reproduction so it lead to variation.

Note: Fertilisation & pollination ~~is~~ is independent of H_2O , but seed germination depend upon H_2O .

- Dormancy & dehydration is basis of agriculture

* Seed viability

- Lupine (Lupi

- The time period for which seed retain the capacity to germinate.
- few seeds - Dormancy period for several months
- Most seeds - Dormancy period for years.



- Lupine (*Lupinus arcticus*), isolated from Arctic tundra = 10,000 years (dormancy)
- Date palm (*Phoenix dactylifera*), King herod place near dead sea = 2000 years (dormancy)
- In orchid, *Strigas Orobanche* ^{→ parasitic plant} no tiny thousand seeds are present

* Apomixis

- Seed (embryo) formation without meiosis and fertilisation

Method I.

MMC (megaspore mother cell)

↓ Directly form

embryosac ($2N$)

↓

egg ($2N$)

↓ without fertilisation

Embryo ($2N$)



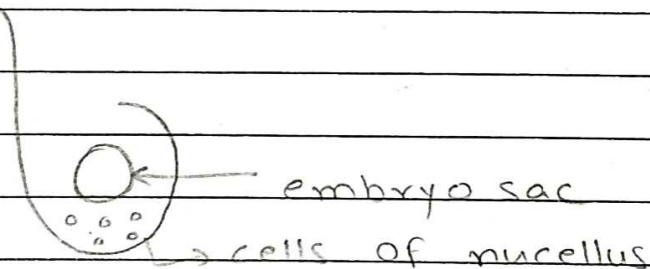
- Apomixis is a type of asexual reproduction (No meiosis, No fertilisation) that mimic sexual reproduction (seed formation, involvement of egg)
- e.g. In asteraceae/compositae family and poaceae/graminae (grass family)

Method II.

Cells surrounding embryo sac called nucellus ($2n$) and these cell formed embryo ($2N$)
eg. citrus, mango

* polyembryony

- ~~form~~ formation of more than one embryo.



- Cells of nucellus forms many embryo & it leads to polyembryony
- All are apomictic and clone embryo.

Principles of Inheritance & Variation

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* Genetics

- Study of heredity and variation
- Father of genetics ÷ Gregor Johann Mendel
- Term genetics given by ÷ Bateson
- Heredity ÷ Transmission of character from parent to offspring (one generation to other)
- Variation ÷ The difference shown by - progeny/offspring which were absent in parents.
- Inheritance ÷ Process by which character transfer from parent to offspring
- Homologous chromosome ÷ Chromosome of same pair.
- Non-homologous chromosome ÷ Chromosome of different pair.

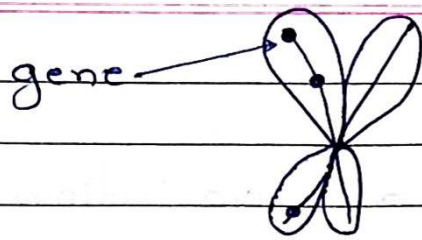
* Gene ÷

- Segment of DNA, which control particular character
- Usually one gene control one character.



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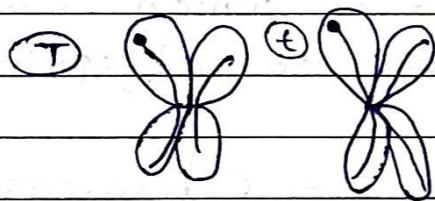
- Term gene given by + Johansenn
- Term factor given by + Mendel

Gene = factor

* Allele

- ~~Atterm~~ Alternate form of one gene/same gene.

Case I: Both allele are disimilar (character + height)



ⓧ ÷ Dominant allele

ⓧ ÷ Recessive allele

Homologous chromosome

$2n = Tt \rightarrow$ tall trait

- allele are present on same locus/homologous site on homologous chromosome.

• $T \div$ Tall trait

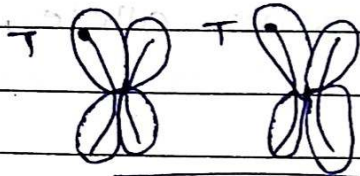
• $t =$ Dwarf trait

- In this case only T (dominant allele) express and t (recessive allele) won't express.



- If both alleles are dissimilar on homologous chromosomes, this condition is known as heterozygous condition.

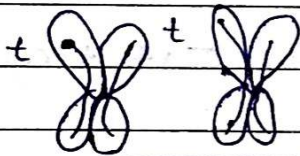
Case II. Both alleles are dominant (TT)



$2n = TT \rightarrow$ Tall trait

- If both alleles are similar on homologous chromosomes, this condition is known as homozygous condition.

Case III. Both alleles are recessive (tt)



$2n = tt \rightarrow$ Dwarf trait

$\rightarrow$ homozygous condition

- Term allele, homozygous and heterozygous is given by $\div$ Bateson.

Conclusion from above cases

(i) $2n = TT$

$\rightarrow$ Homozygous, dominant allele, tall, dominant trait



(2) $2n: Tt$

↳ Heterozygous, dominant allele, tall, dominant trait.

(3) $2n: tt$

↳ Homozygous, recessive allele, Dwarf, recessive trait.

* Mendelism

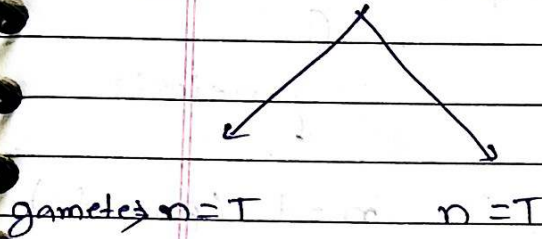
- Mendel worked on garden pea (^{sativum} *Pisum*)
- Born in 20 July 1822, in Austria
- Worked in Augustinian monastery for 7 years (1854-61)
- He studied 7 characters or 14 traits or 7 pairs of traits of pea.

	Character	Dominant trait	Recessive trait
1	plant height	Tall (T)	Dwarf (t)
2	Seed colour	yellow (Y)	green (y)
3	Seed shape	Round (R)	wrinkled (r)
4	flower colour	violet	white
5	pod colour	green	yellow
6	pod shape	full/inflated	Constricted
7	flower position	Axillary	Terminal



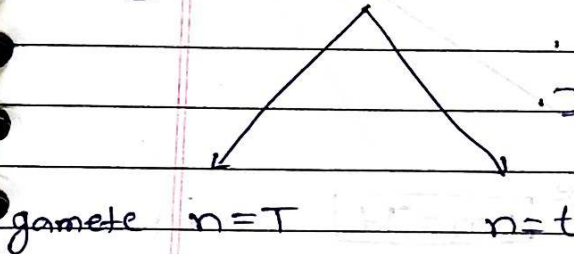
* Gamete formation

① $2n = TT$ (δ or ϕ parent)



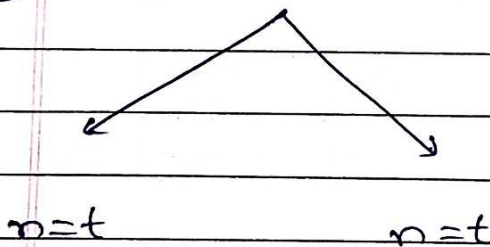
- no. of gamete = 2
- same type of gamete

② $2n = Tt$



- no. of gamete = 2
- Different type of gamete

③ $2n = tt$



- no. of gamete = 2
- same type of gamete

* Inheritance of one gene

- Study of one gene/one character (plant height / two trait (Tall & dwarf) is called monohybrid cross



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- Homozygous parents

(10cm) ♂ parent ($2n = TT$)

♀ parent ($2n = tt$) (3cm)

meiosis

meiosis

$n = T$ (gamete)

$n = t$ (gamete)

zygote

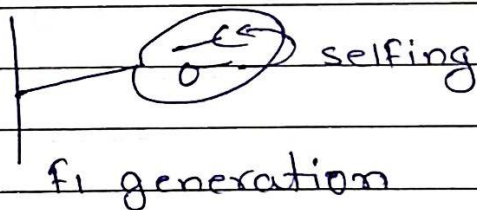
$2n = Tt$

10cm

F₁ generation

(first filial generation)

- F₁ generation is not intermediate b/w parents



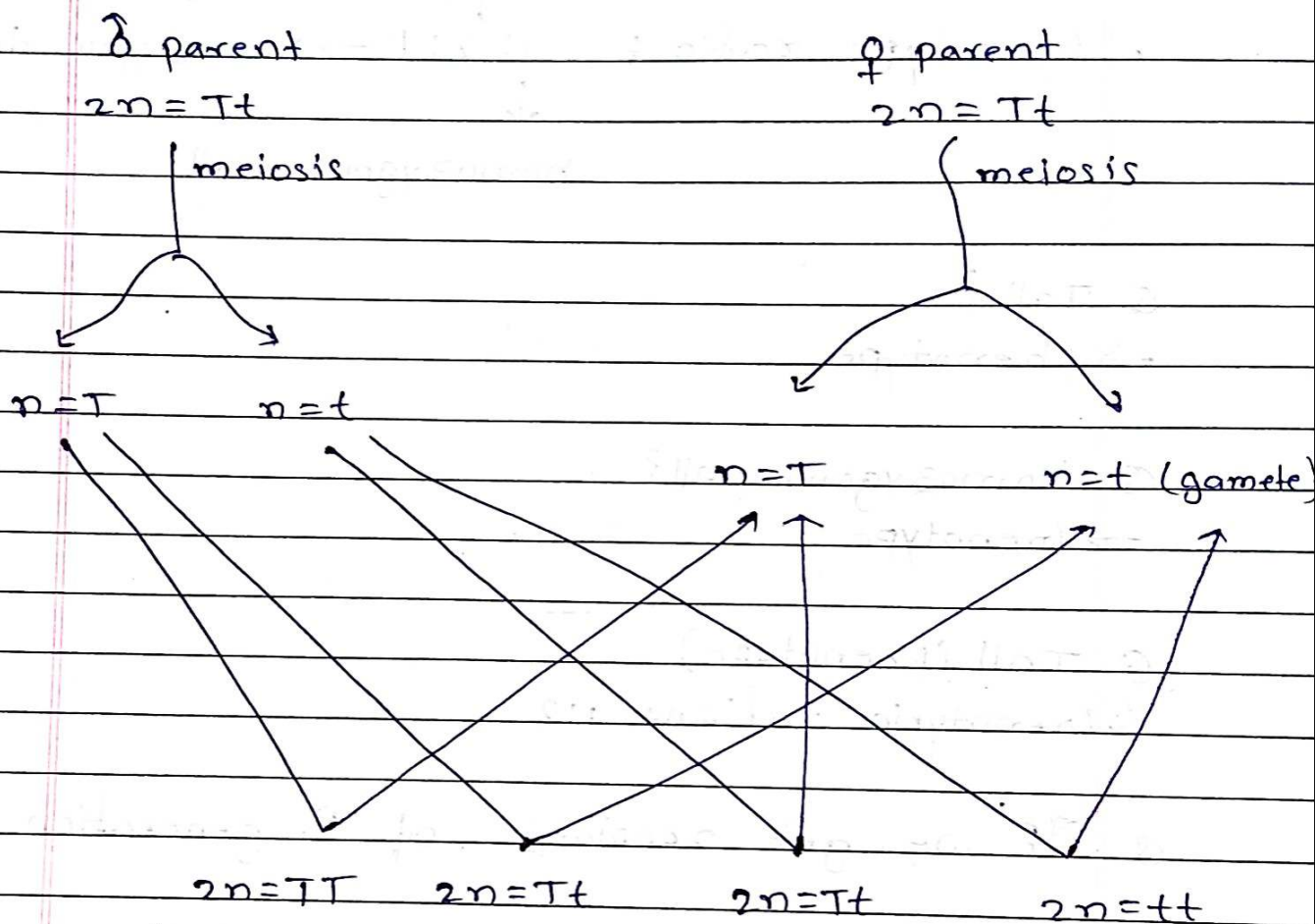
♂ parent (stamen)
 $2n = Tt$

♀ parent (pistil)
 $2n = Tt$



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ϕ δ F_2 generation

		$\textcircled{T}$	$\textcircled{t}$	δ gamete
ϕ gamete	$\textcircled{T}$	TT	Tt	
	$\textcircled{t}$	Tt	tt	

→ physical appearance of organism = 2 (Tall & Dwarf)
(phenotype)

→ phenotype ratio: 3:1 (dwarf)
(Tall)

→ genetic constitution of organism = 3
(genotype)



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 $\rightarrow$ Heterozygous tallGenotype ratio $\div$ 1:2:1 $\rightarrow$ Homozygous dwarf

homozygous tall

Q. Tall?

 $\rightarrow$ phenotype

Q. Homozygous tall?

 $\rightarrow$ Genotype

Q. Tall (phenotype)

 $\hookrightarrow$ Genotypic ratio $\div$ 1:2Q. If we get 200 plants of F_2 generation

(i) No. of Heterozygous tall?

$$= \frac{2}{4} \times 200 = 100$$

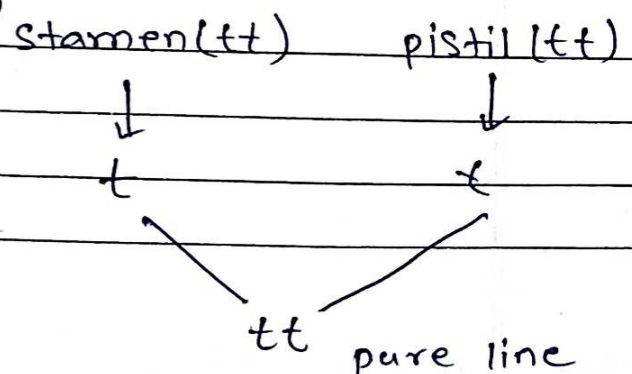
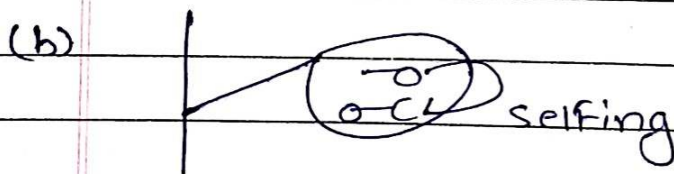
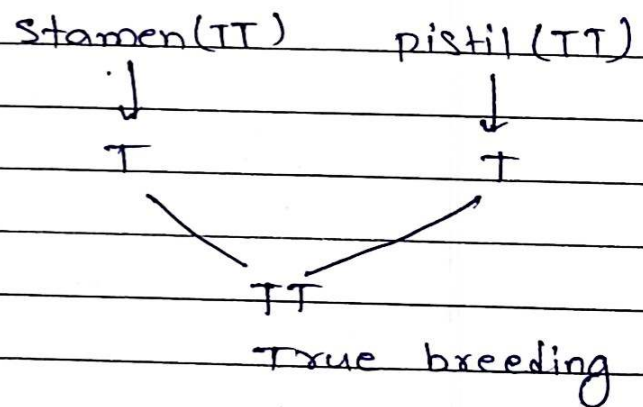
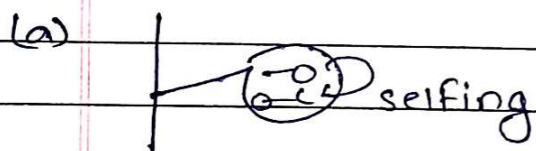
(ii) No. of Dwarf

$$= \frac{1}{4} \times 200 = 50$$



* Reason of Mendel Success

- (1) first time he used statistics & mathematical tool.
- (2) He kept record of his experiments
- (3) His works proved by experiments
- (4) Large sampling size
(He repeated same experiment with many plants)
- (5) Study one character at a time
- (6) He used true breeding line/ pure line/ homozygous.



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③

stamen (Tt)

pistil (Tt)

offspring: TT, Tt Tt tt

↳ not pure line

Molecular basis of Inheritance



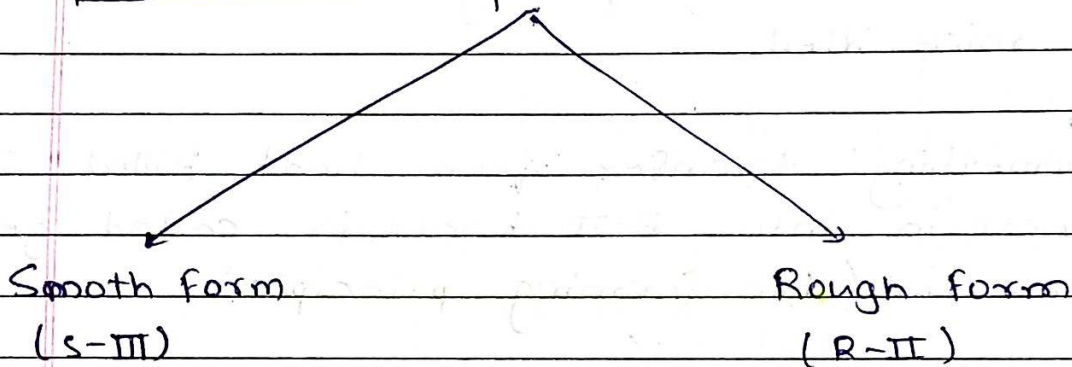
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* DNA is a genetic material

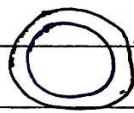
(1) Transformation experiment

→ ~~given~~ by Frederick Griffith (1928)

- He use both forms of Streptococcus pneumoniae or pneumococcus bacteria



(a) Smooth bacteria



← polysaccharide (sugar)
or mucus

→ Cell of smooth bacteria shine due to sugar layer

→ Capsule is present, pathogenic bacteria (virulent)

(b) Rough bacteria

→ polysaccharide is absent

→ Capsule is absent

→ Non-pathogenic (non-virulent)

case I. Mice + R-II $\longrightarrow$ No death

case II. Mice + S-III $\longrightarrow$ death

case III. Mice + S-III (heat killed) $\longrightarrow$ No death

case IV. Mice + R-II + S-III (heat killed) $\longrightarrow$ death

($\rightarrow$ Note: We were expecting a no death, but mice died

Something transfer from heat killed S-III bacteria into R-II bacteria called genetic material (transforming principle)

$\downarrow$

So R-II bacteria developed capsule and change into living S-III bacteria which killed mice

Note: He didn't explain biological nature of genetic material

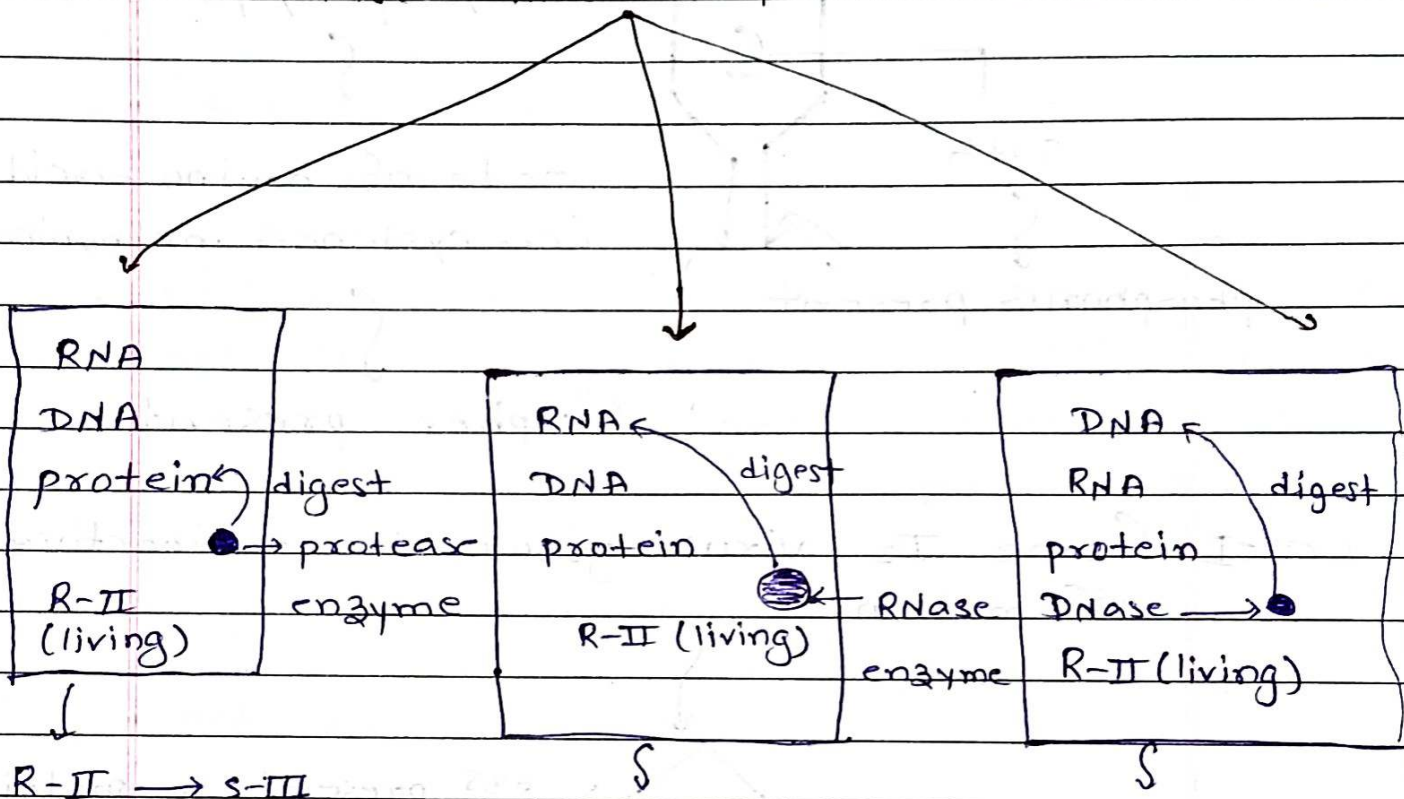
- Avery, Macleod & McCarty discovered biological nature of genetic material is DNA.



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Extract from heat killed ^{S-III} bacteria
transfer into test tube



So, DNA is genetic material.

(2) Hershey & Chase (1952) experiment

$\rightarrow$ They gave unequivocal proof that DNA is genetic material

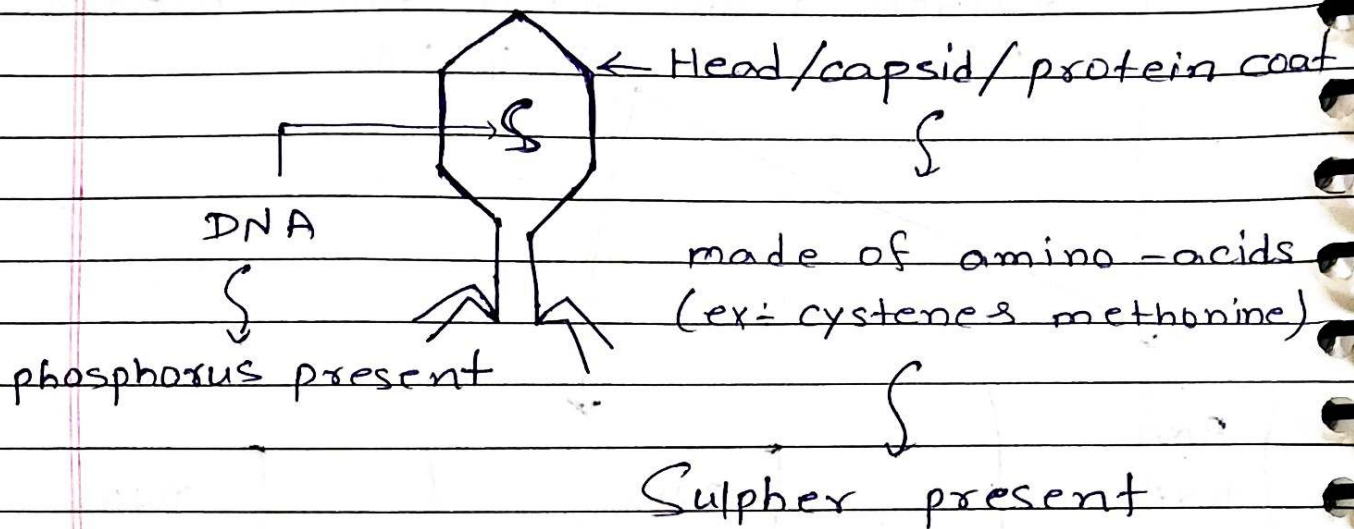
$\rightarrow$ They use E-coli bacteria & T₂ virus. T₂ virus infect E-coli, so T₂ virus is bacteriophage.

$\rightarrow$ They use radioactive isotopes: ³⁵S & ³²P

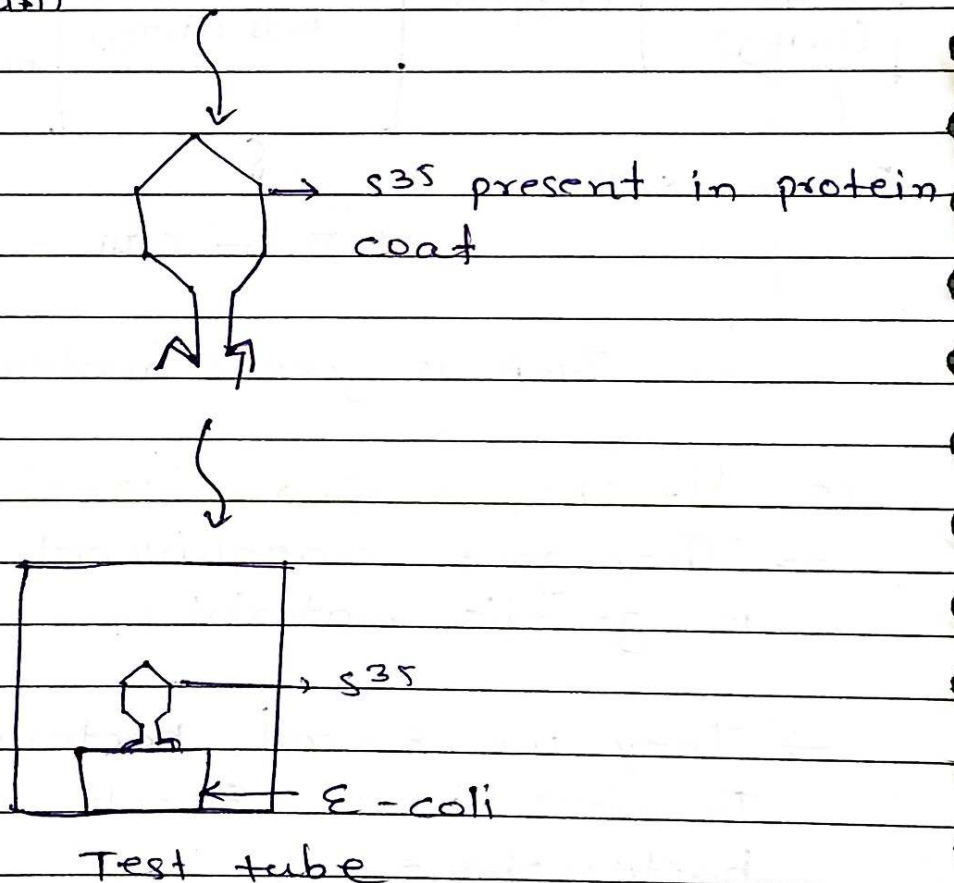


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Case I Some T₂ virus grown in radioactive ³⁵S medium



• T₂ virus infect E. coli bacteria

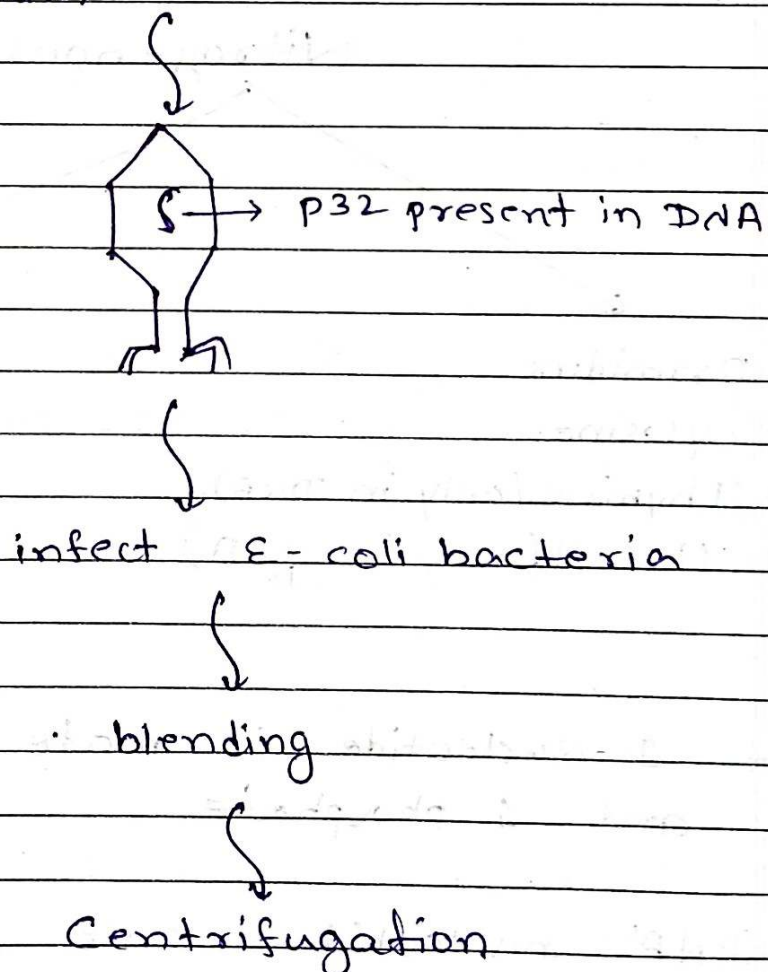


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- Remove the contact b/w virus & E-coli bacteria (blending)
- Centrifugation is done (separation of virus & bacteria on the basis of density)
- S^{35} radio activity found in supernatant part, it means protein coat (S^{35}) present in supernatant part, protein coat not enters in bacteria, So protein is not genetic material

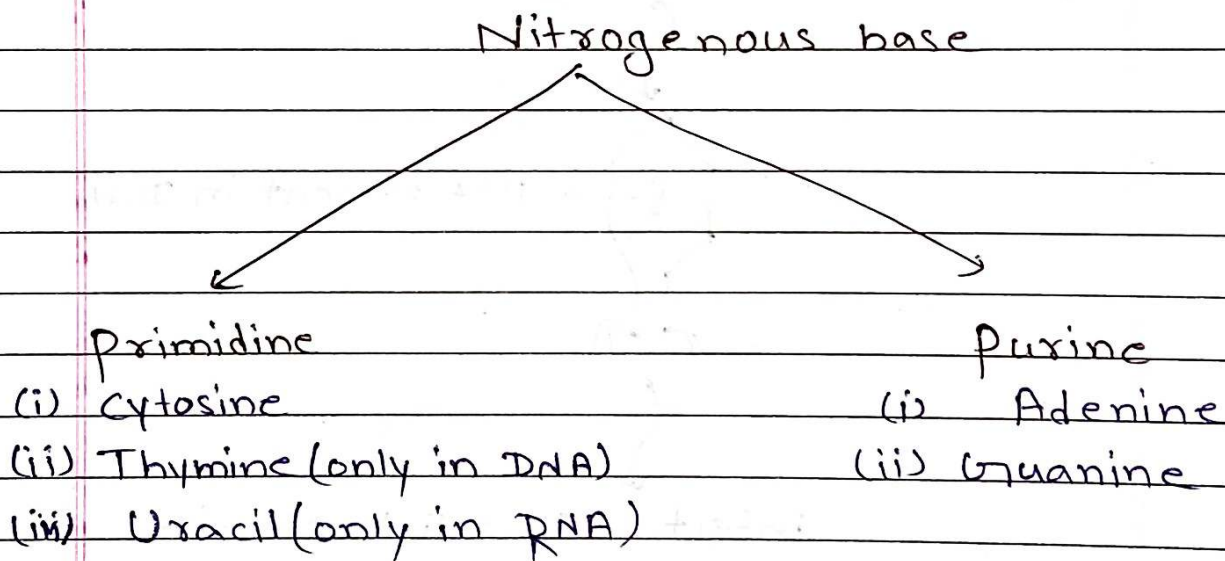
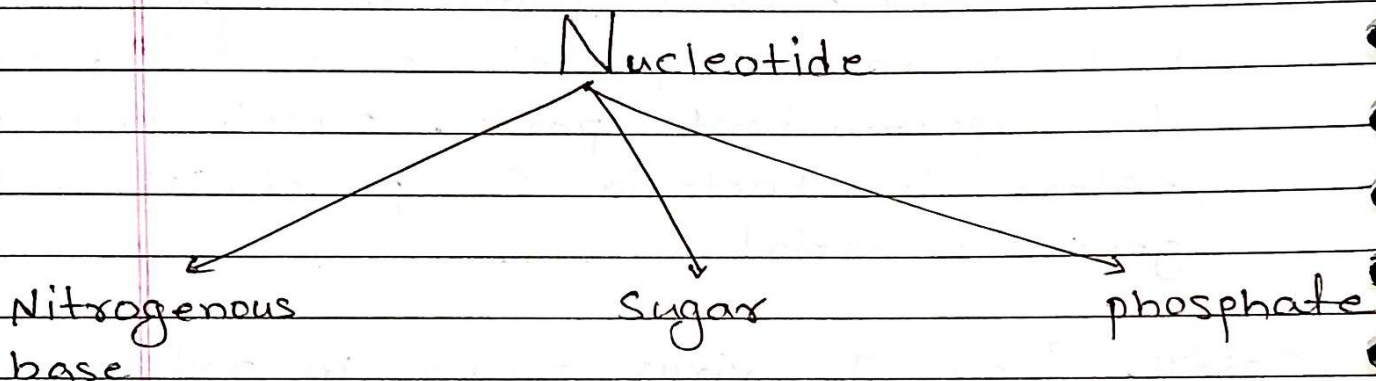
Case II. Some T_2 virus grown in radioactive P^{32} medium





- P^{32} radioactivity found in bacteria in pellet region, it means DNA enters into bacteria. So DNA is genetic material.

* Nucleotide



Note:- 1 Nucleotide is made of 1 base, 1 sugar and 1 phosphate.

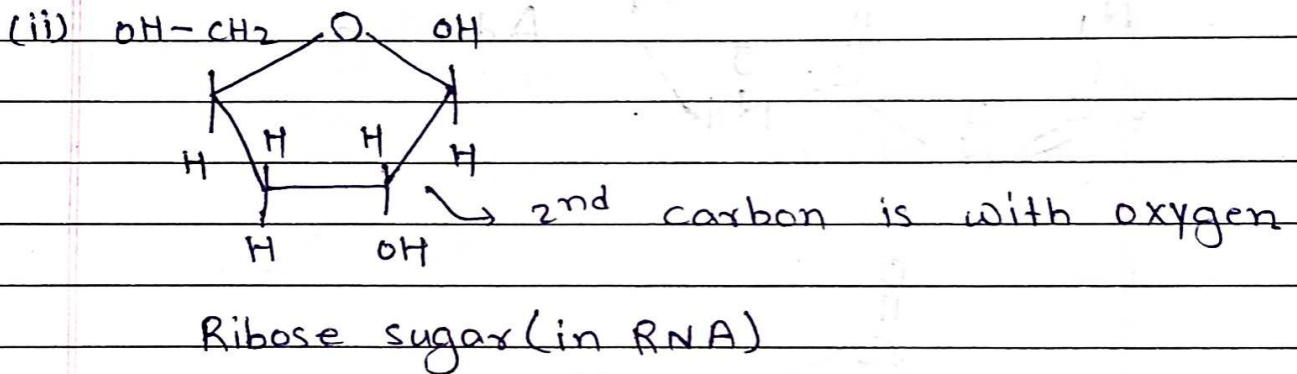
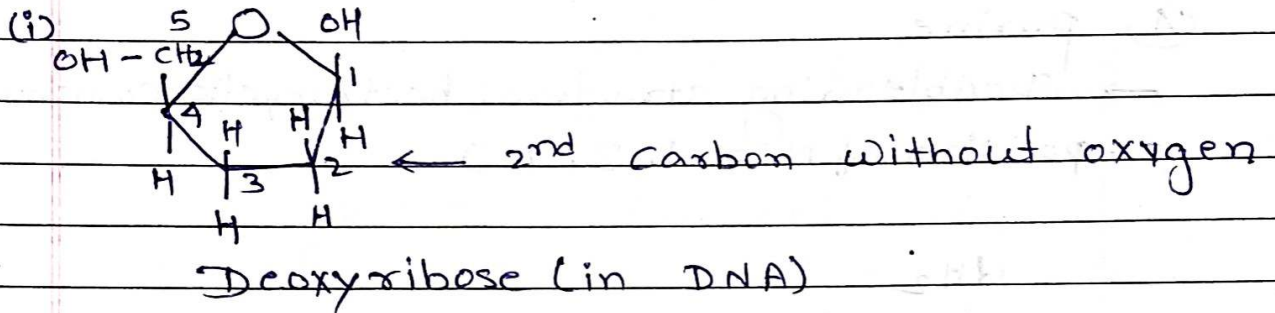
- DNA's nucleotide = base + Deoxy ribose - sugar + phosphate
- RNA's nucleotide = base + ribose sugar + phosphate



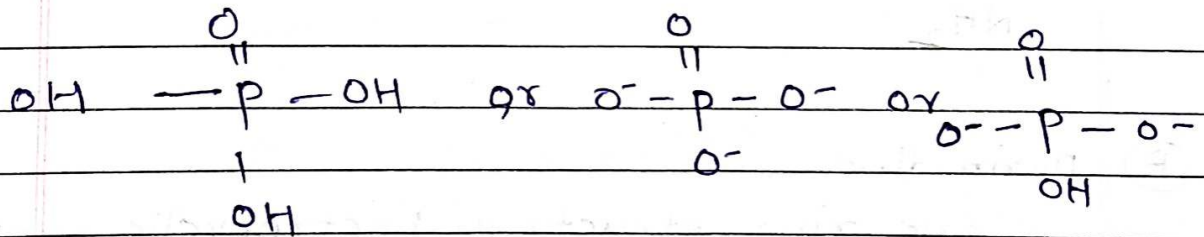
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(1) Sugar



(2) phosphate





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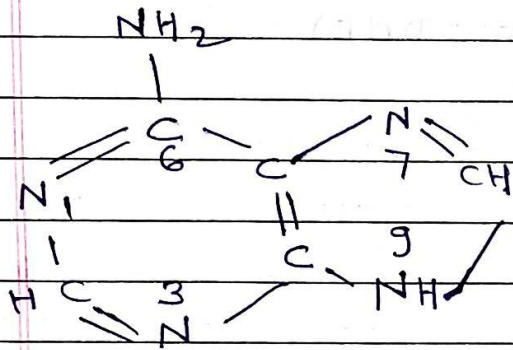
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③ Nitrogenous base

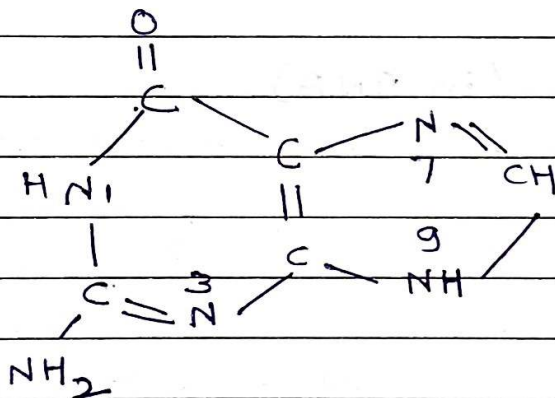
① purine

→ Double ring structure (heterocyclic compound)

→ position of N = 1, 3, 7, 9



Adenine

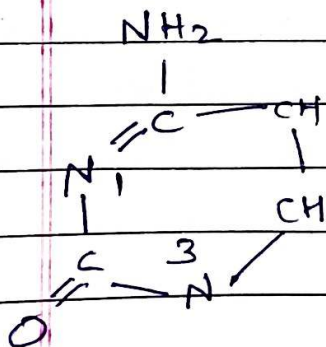


Guanine

② pyrimidine

→ single ring structure (heterocyclic compound)

→ position of N = 1st & 3rd

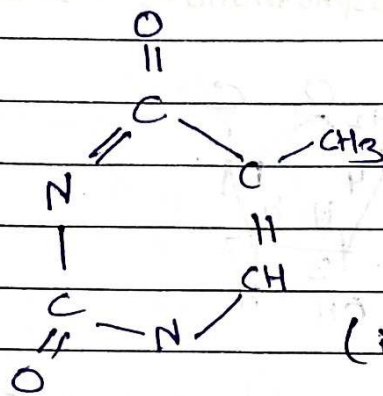


Cytosine

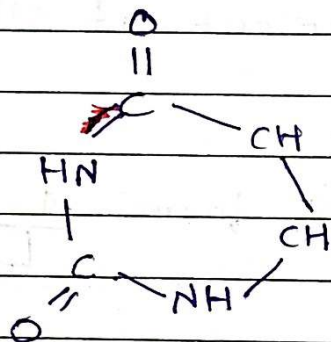


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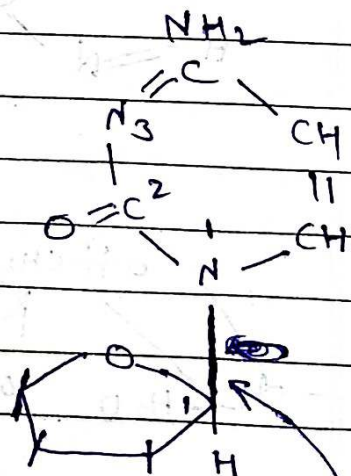
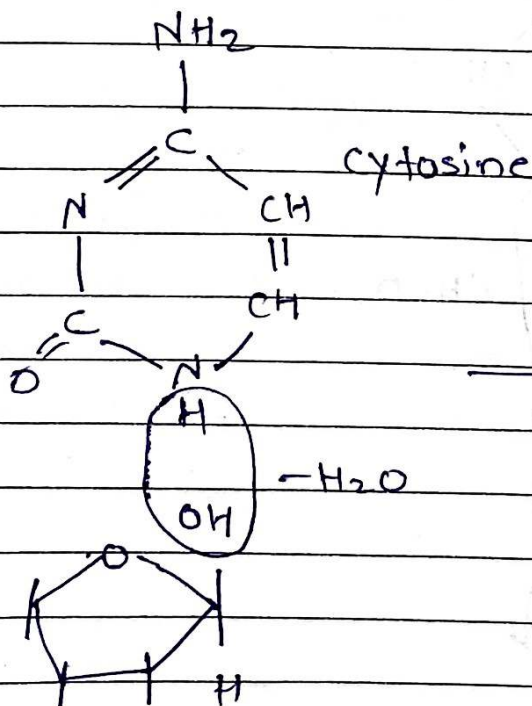
Thymine (5-methyl
uracil)
(in DNA only)



Uracil (RNA only)

* Formation of Nucleotide (pyrimidine base)

↳ Base, sugar, phosphate

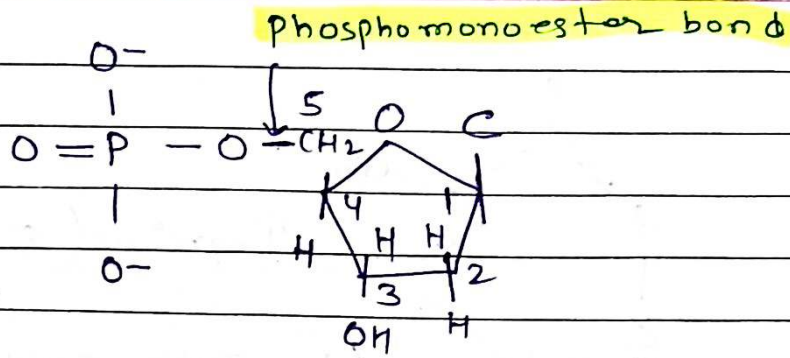


(1' - 1' → glycosidic
bond)



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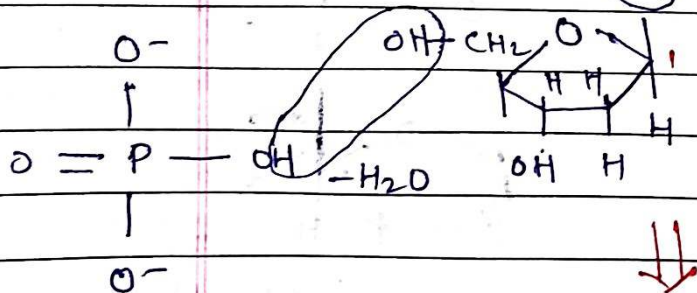
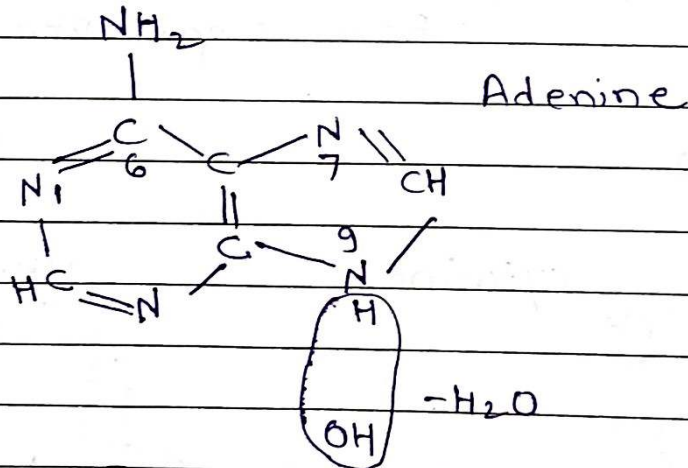
3' → OH group of sugar present at 3rd c

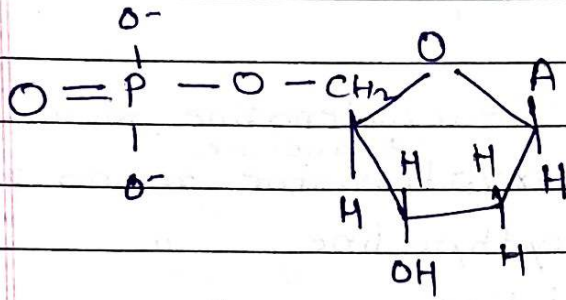
5' → phosphate present at 5th carbon of sugar

Note: pyrimidine always forms 1-1' glycosidic bond.

↳ 1st carbon of base & 1st c of sugar

* Formation of Nucleotide (purine base)



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Nucleotide

Note: Purine always form 1-9' glycosidic bond

→ 9th carbon of base
→ 1st carbon of sugar

Note: Two nucleotides attached with each other by phosphodiester bond (3'-5' attachment)

★ DNA's Nucleotide

Base + Sugar $\Rightarrow$ Nucleoside

Base + Sugar $\longrightarrow$ Nucleoside

Adenine + Deoxyribose $\longrightarrow$ Deoxyadenosine

Guanine + " $\longrightarrow$ Deoxyguanosine

Thymine + " $\longrightarrow$ Deoxythymidine

Cytosine + " $\longrightarrow$ Deoxycytidine



Nucleoside + phosphate $\rightarrow$ Nucleotide

- ① Deoxyadenosine + p $\rightarrow$ Deoxyadenosine mono phosphate
② Deoxyguanosine + p $\rightarrow$ ^{Guanosine} Deoxyadenosine mono phosphate
③ Deoxythymidine + p $\rightarrow$ Deoxythymidine " "
④ Deoxycytidine + p $\rightarrow$ Deoxycytidine " "

① dAMP ② dGMP ③ dTMP ④ dCMP

$\Rightarrow$ RNA's ~~DNA~~ Nucleotide

Base + Sugar $\rightarrow$ Nucleoside

Adenine + ribose $\rightarrow$ Adenosine
Guanine " $\rightarrow$ Guanosine
Uracil " $\rightarrow$ Uridine
Cytosine " $\rightarrow$ Cytidine

Nucleoside + phosphate $\rightarrow$ Nucleotide

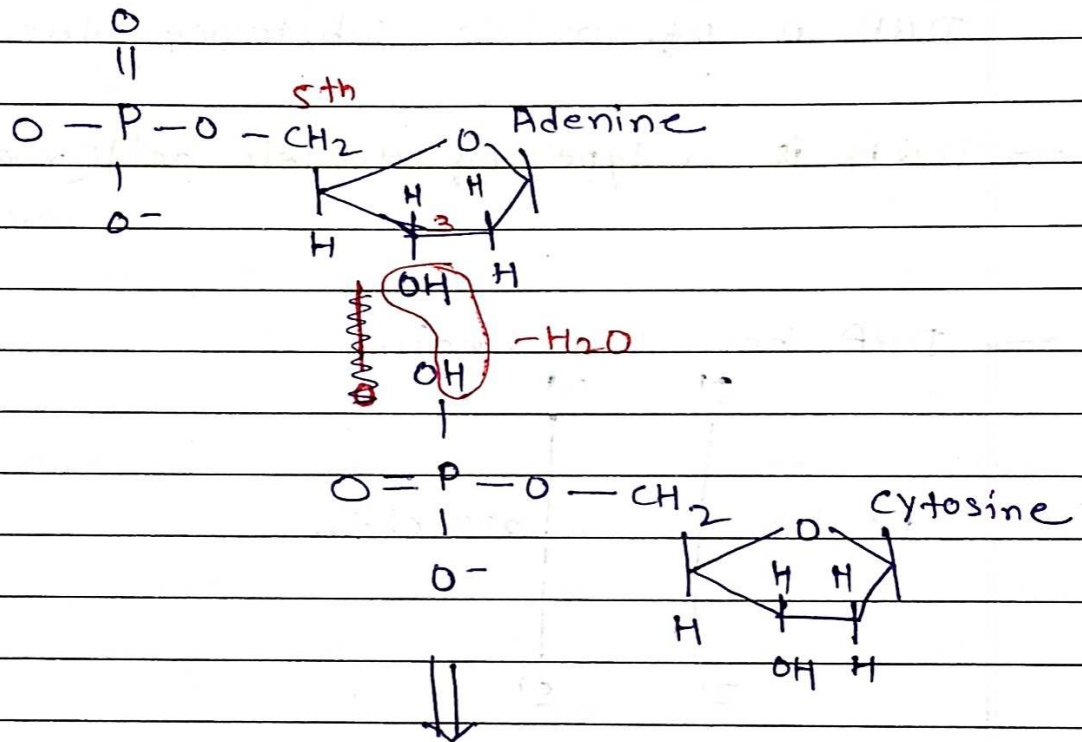
Adenosine + p $\rightarrow$ Adenosine mono phosphate
Guanosine + p $\rightarrow$ Guanosine "
Uridine + p $\rightarrow$ Uridine "
Cytidine + p $\rightarrow$ Cytidine "



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* phosphodiester bond.



AMP

← phosphodiester bond

CMP

(DNA's chain)



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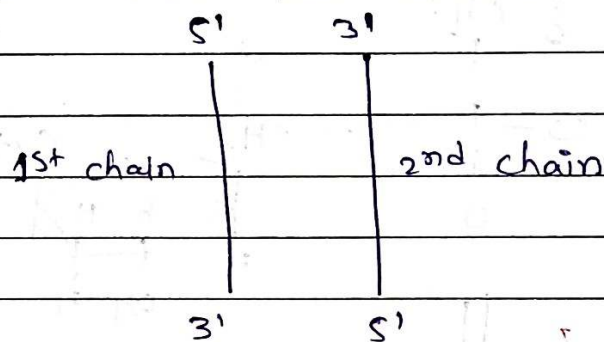
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* DNA

→ Friedrich Meischer (1869) identified that DNA is of acidic substance (due to phosphate)

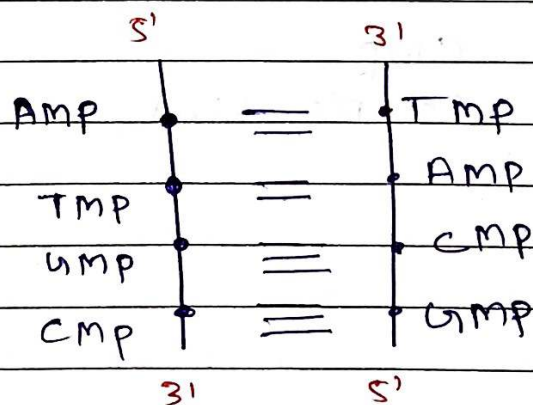
→ DNA is a type of nucleic acid (made of nucleotides)

→ DNA has two chain



* Rough diagram of DNA

↳ 2 chain



Q. Total nucleotide

= 8

Q. Total base = 8

Q. Base pair = 4

↳ $\frac{\text{base}}{2} = 4$

Q. Sugar? nucleotide = 1 sugar
= 8

Q. Glycosidic bond = 8

Q. phosphodiester bond = 6 = no. of base - 2

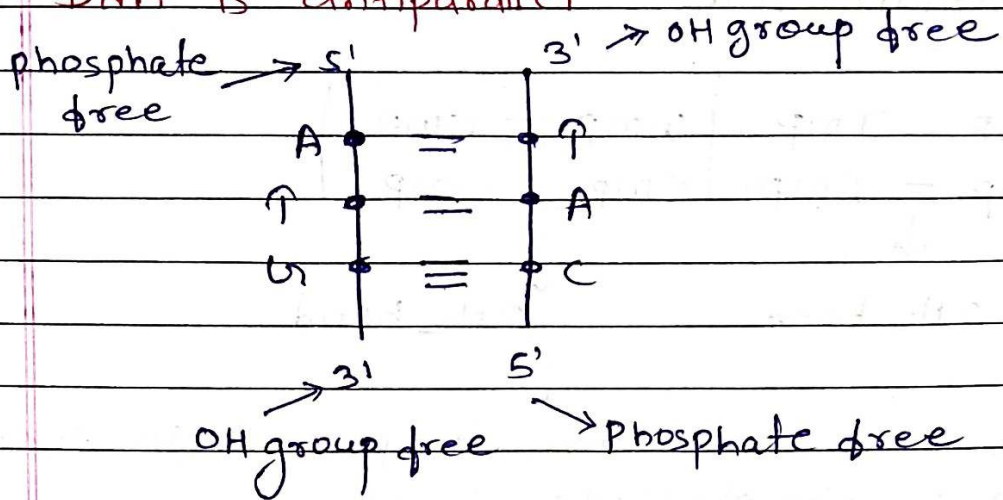
↳ in linear DNA

- $\text{AMP} \equiv \text{TMP}$ | $\text{UMP} \equiv \text{CMP}$ |
 $\text{TMP} \equiv \text{AMP}$ | $\text{CMP} \equiv \text{UMP}$ |
 ↓ ↓
 2H₂ bond 3H₂ bond

Note: prokaryotes has circular DNA. So no. of phosphodiester = no. of base = no. of nucleotide



- DNA is antiparallel



* Structure of DNA

- Franklin and Wilkin, They allow 'x' rays on DNA & generate a 'x' ray pattern of DNA (X ray Diffraction)

Technique: X ray crystallography

Result: DNA is a double helical structure, made up of two chains, But they did not provide detail of double helix structure of DNA.

- Chargaff rule (valid for ds DNA)

① No. of pyrimidine = No. of purine

$$\Rightarrow C + T = A + G$$

$$\Rightarrow \frac{C + T}{A + G} = 1$$



② $\frac{A+T}{G+C}$ ratio is specific for species

③ Adenine equal^{to} Thymine
($A = T$)
 $\rightarrow 2H_2$

Guanine equal to cytosine
($G = C$)
 $\rightarrow 3H_2$

- Above two studies helped Watson & Crick. They proposed double helical structure of DNA (1953)

④ Adenine = 10
Guanine = ?

$$\rightarrow A + T + G + C = 100$$

$$10 + 10 + G + C = 100$$

$$G + C = 80$$

$$G = C = 40$$

⑤ Adenine (Amp) = 10
Total H_2 bond = ?

$$A = 10, T = 10$$

$$A + T = 20$$

$$A = T$$

$$1 \text{ base pair} = 10$$

$$1 \text{ base pair} = 2H_2$$

$$10 \text{ base pair} = 20H_2O$$

* Length of DNA = No. of base pair $\times$ 0.34 nm

$G + C + A + T = 100$

$G + C = 80$ base / 40 base pair

$G \equiv C$

$\rightarrow 3H_2$

40 base pair = 120 H_2

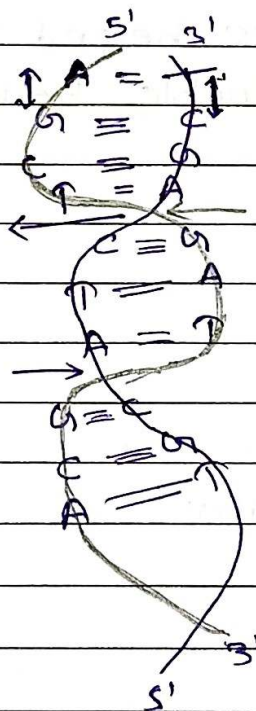
Total H_2 bond = 120 + 20 = 140 H_2

* Watson and Crick

Helix length

minor groove

major groove



• DNA is antiparallel

• B-Type of DNA or right hand DNA / clockwise DNA

• Helix length / one turn of DNA = No. of base pair $\times$ distance b/w two base pair
 $= 1069 \times 3.4 \text{ \AA} / 0.34 \text{ nm}$
 $\Rightarrow 34 \text{ \AA} / 0.34 \text{ nm}$

* Diameter of DNA = 20 $\text{\AA}$

Length of human DNA = No. of base pair $\times$ distance b/w two base pair
 $= 6.6 \times 10^9 \text{ bp} \times 0.34 \times 10^{-9} \text{ m}$
 $= 2.2 \text{ metre}$



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Q. If adenine = 120

Total coils/turn = 20

No. of pyrimidine which form Triple bond.

$$G \equiv C \rightarrow \text{pyrimidine}$$

Q. DNA Turn = 20

1 Turn = 10 bs

20 Turn = 200 bs $\Rightarrow$ 400 bases (Total base)

adenine : 120 = Thymine

$$G + C = 400 - 140 = 260$$

$$C = \frac{260}{2} = 130 \text{ pyrimidine which form Triple bond.}$$

Q. 6 coils

22 bp linked with 2 hydrogen bond

Cytosine?

$$\rightarrow \text{Total bp} = 6 \times 10 = 60, \text{ base} = 120$$

$$T + A = 44$$

$$C + G = 120 - 44 = 76$$

$$C = G = \frac{76}{2} = 38$$



Q. If length of DNA $340 \text{ \AA}$
No. of base pair

$$\rightarrow 340 = bs \times 3.4 \text{ \AA}$$

$$bs = \frac{340}{3.4} = 100$$

Q. DNA is $340 \text{ \AA}$, Thymine = 20, Guanine?

$$bs = 100, \text{ Thymine} = 20 = \text{Adenine}$$

$$base = 200$$

$$G + C = 200 - 40$$

$$G + C = 160$$

$$G = C = 80$$

Note: $\text{Length of DNA} = \text{No. of turn} \times 34 \text{ \AA}$
 $\rightarrow$ or, No. of helix

Note: $A = T$ [Complementary
 $G = C$ base pairing]

$\rightarrow$ unique property of DNA

Note: Who provide stability to DNA

(i) H_2 bond ~~in~~ B/w base of nucleotide

(ii) Base stacking (one bp ~~is~~ above other)



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Note: Backbone of DNA: Sugar-phosphate
(phosphodiester bond)

Note: Base of DNA projected inward.

Q. Why the distance b/w two chain is uniform?

→ Because H_2 bond always form b/w purine and pyrimidine

Note:

Ø x174 (bacteriophage)

↳ 5386 base/nucleotide, ss circular DNA

• λ phage

↳ 48502 base pair, ds linear DNA

• E. coli

↳ 4.6×10^6 bp, haploid

• Human

↳ ~~66~~ 66×10^9 bp (44 chromosome)

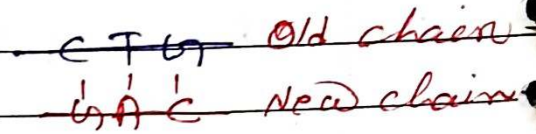
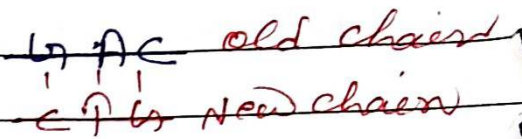
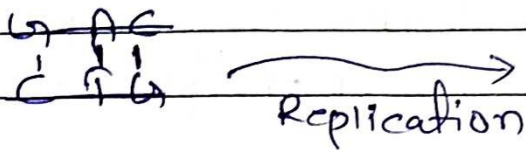
• Human (genome)

↳ Haploid set of chromosome (23 chromosome)
↳ 3.3×10^9 bp



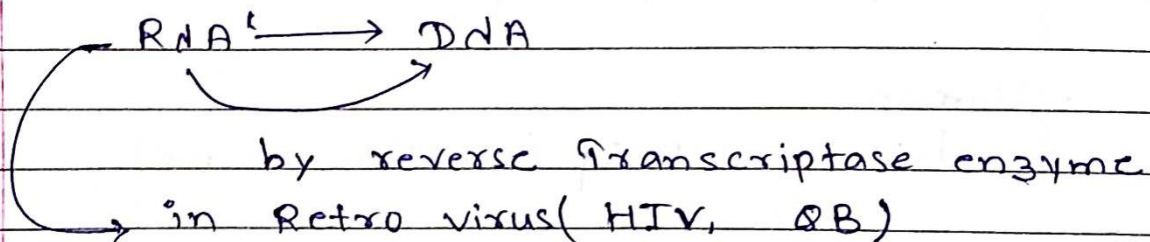
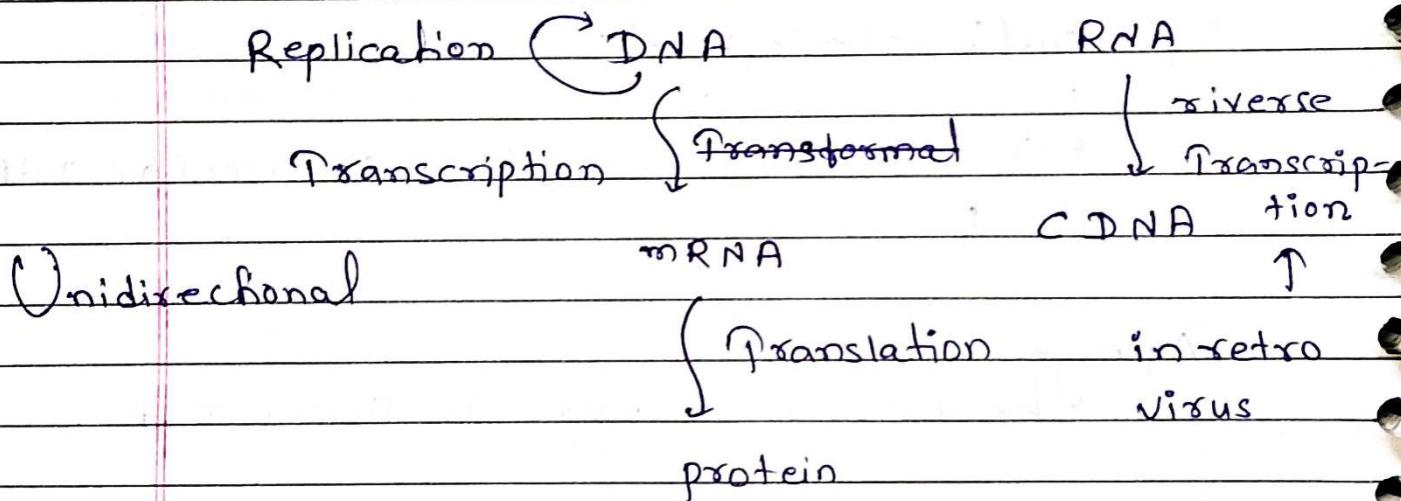
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Daughter DNA

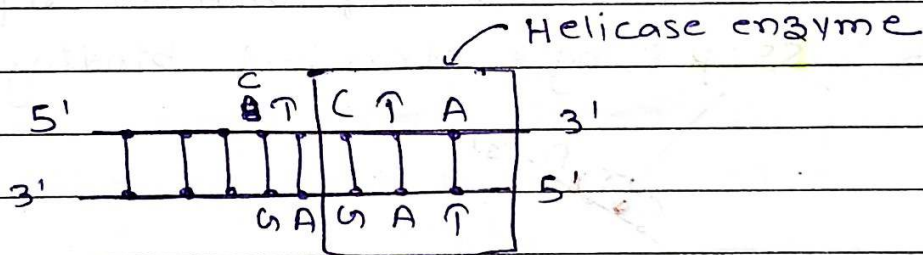
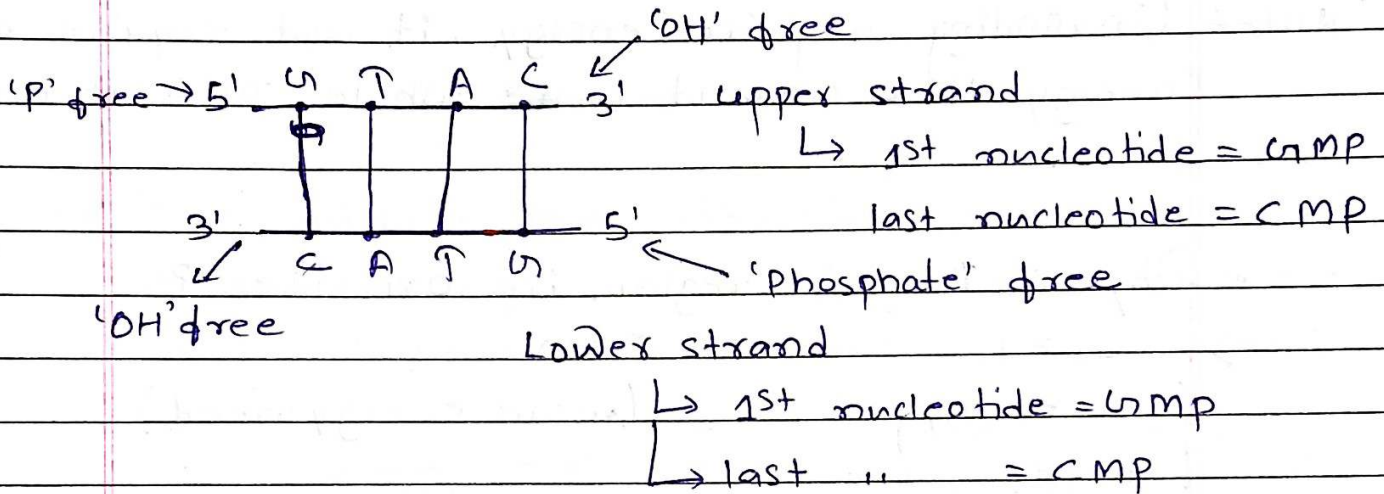
* Central Dogma
↳ By crick



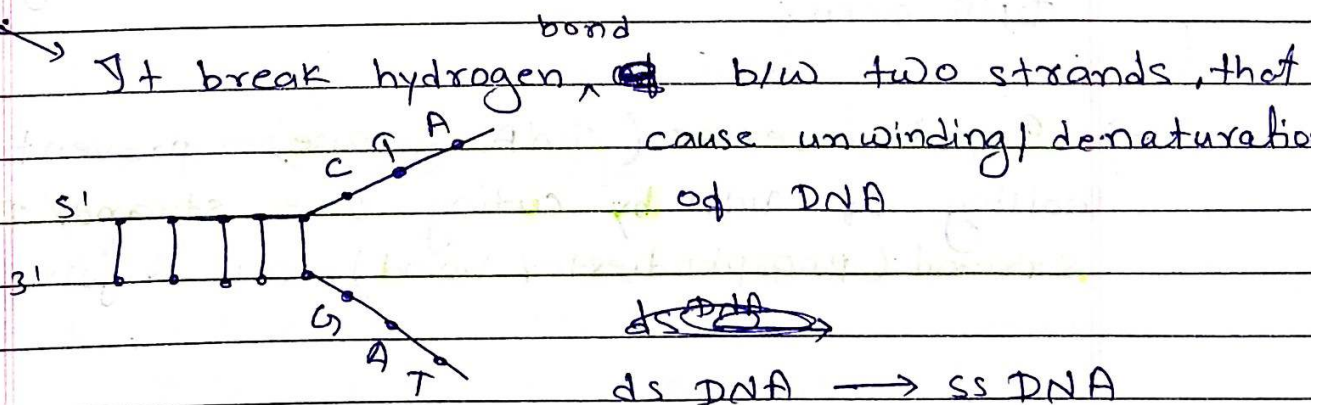
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DNA replication

- DNA synthesis: **5' → 3' Direction**



- Helicase/Unwindase enzyme binds to particular region of DNA (A-T rich region) or ori region (origin of replication) where DNA replication start





→ Replication fork formed due to unwinding.

Note: Unwinding require energy. it ~~can~~ require more energy to ~~unwind~~ ~~whole~~ whole DNA at once time.

• Why A-T-rich region in ori site?

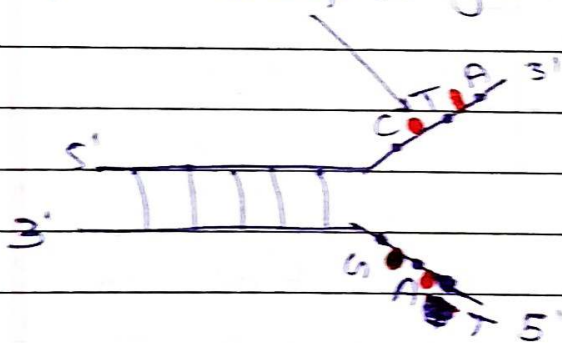
→ A = T

C = G

(less energy need)

(more energy need)

• prevent reassociation of DNA at replication fork + **SSBP** (single strand binding protein)



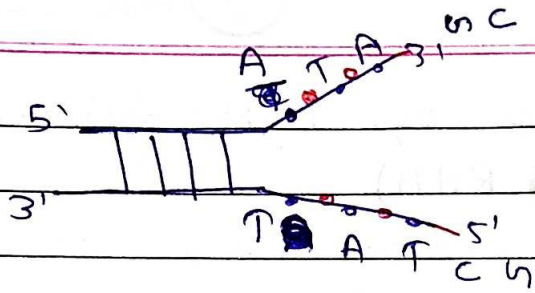
→ Due to helicase activity, super coiling of DNA occur

→ **Topoisomerase** (DNA gyrase) prevent super-coiling of DNA by cutting one strand/two strand (phosphodiester bond) and rejoin it



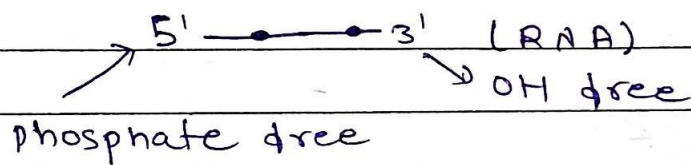
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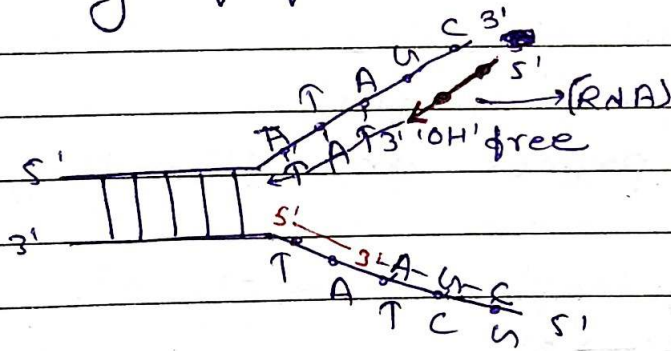


→ DNA synthesis : $5' \rightarrow 3'$

→ To initiate DNA replication we require a segment of RNA known as RNA primer synthesis by primase enzyme.



bind with DNA strands
RNA primer provide its 3'-OH group for binding of first nucleotide of DNA



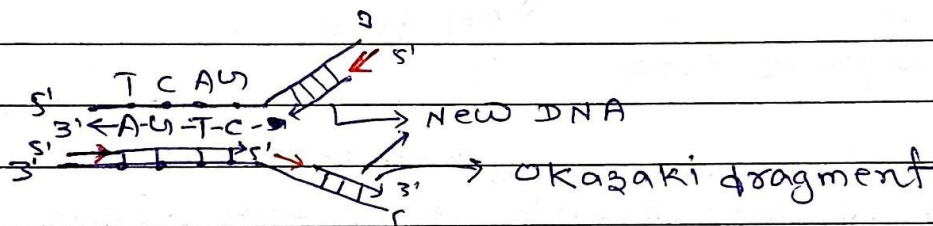
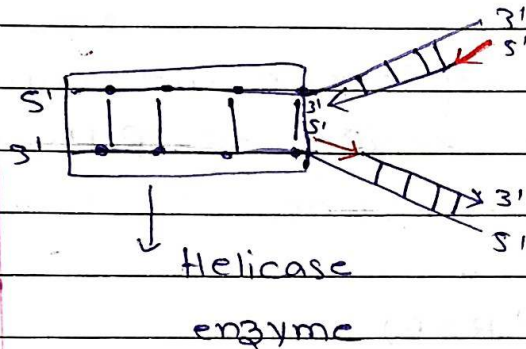
- DNA Addition of Nucleotide induce by DNA polymerase enzyme, result in DNA synthesis
- DNA polymerase enzyme form nucleotide a/c to a template nucleotide, so its called DNA dependent DNA polymerase



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- primase is a type of RNA polymerase,
• (synthesis ~~of~~ RNA)
- primer is single strand.



- Leading strand
 - Towards replication fork
 - Need single primer and strand synthesis continuously
 - Direction of template $3' \rightarrow 5'$
 - Synthesis $5' \rightarrow 3'$



- Lagging strand

- Away from replication fork
- Need more than one primer, synthesis discontinuous.
- direction of template $5' \rightarrow 3'$
- Lagging strand divided in okazaki fragment
- Synthesis $5' \rightarrow 3'$

Note: In prokaryotic, three types of DNA polymerase found

① DNA pol-1 (Kornberg enzyme)

↳ 1000 Nucleotide/min

② DNA pol-2

↳ 50 nucleotide/min

③ DNA-III

↳ 2000bs (per second)

↳ main enzyme

- In eukaryotes, 5 types of DNA polymerase found.

↳ α, β, γ .

- Length of okazaki fragment:

1000-2000 base (prokaryotes)

~~1000~~ 100-200 base (eukaryotes)



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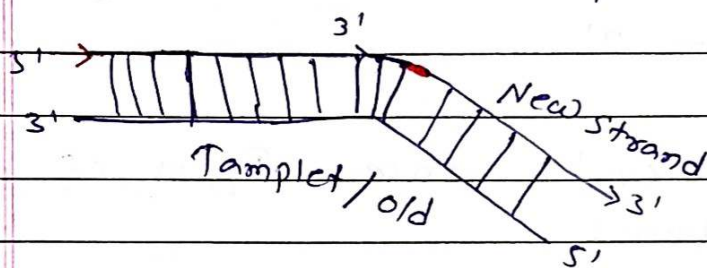
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- primer has 10-12 Nucleotide

- Removal of primer (DNA pol-I)

↳ gap created

↳ nucleotide synthesis (gap due to removal of primer)



- DNA ~~ligase~~ ligase (molecular glue) form pb ~~into~~
- DNA replication is Semi-discontinuous & Semiconservative (50% new DNA, 50% old DNA)
- DNA base pol-III remove wrong base, add correct base during checking process known as exonuclease activity / proof reading
- Direction of exonuclease activity

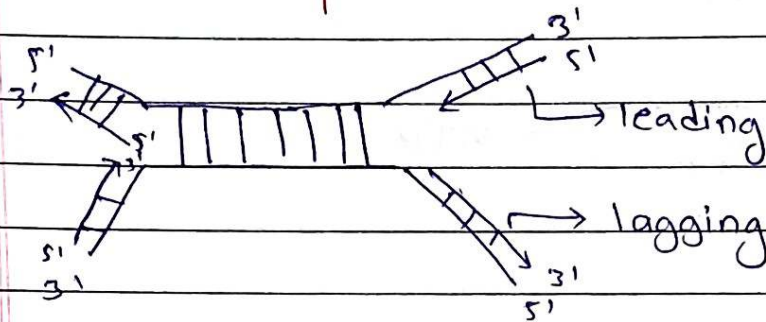
	Exonuclease	polymers action
DNA-pol-I	3' → 5' & 5' → 3'	5' → 3'
DNA pol-II	3' → 5'	5' → 3'
DNA pol III	3' → 5'	5' → 3'



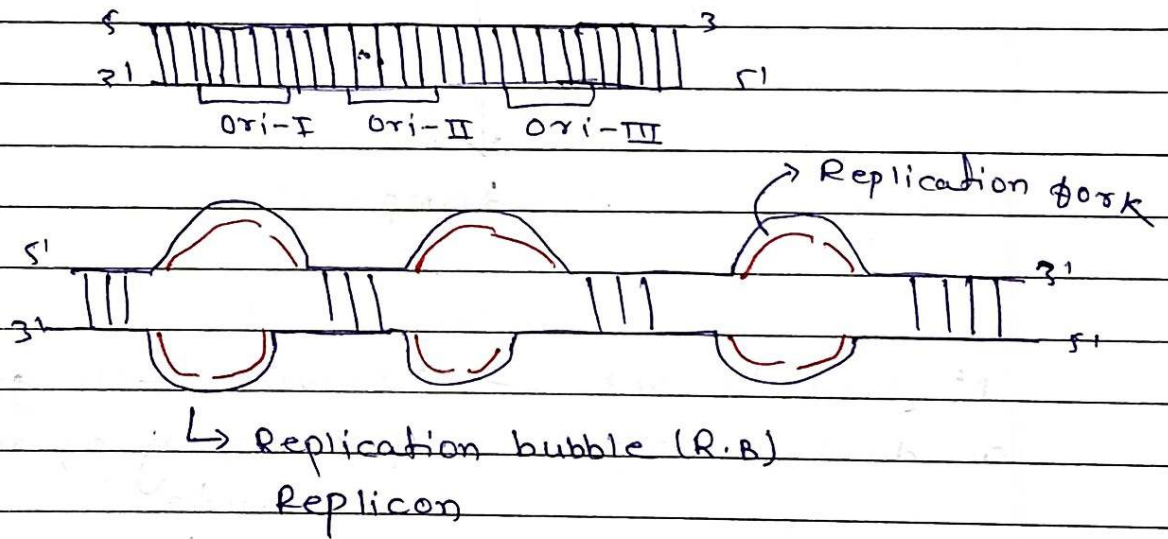
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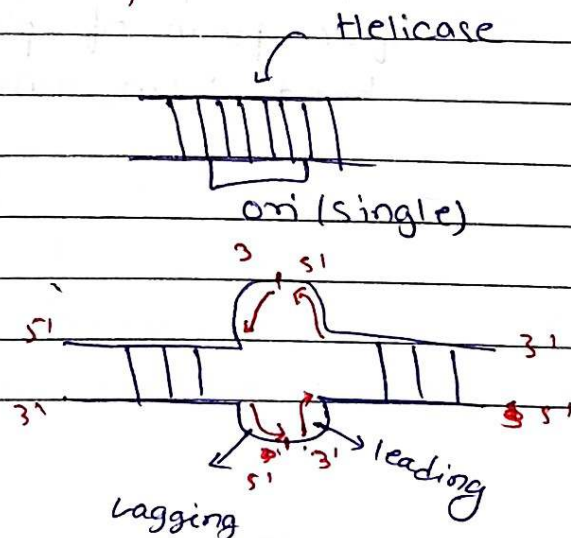
Note: DNA replication is bidirectional



- In eukaryotic DNA, there are more than thousand ori present



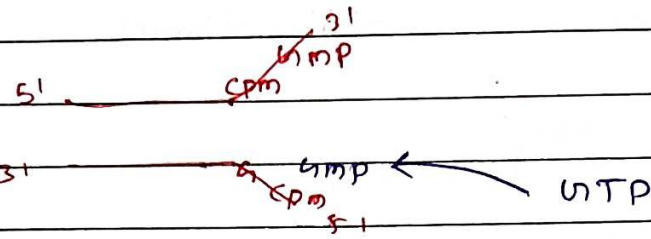
- In prokaryotic DNA, there are less ori site than eukaryotic DNA



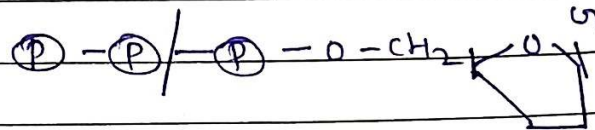


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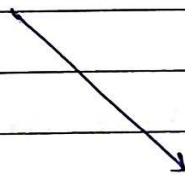


dGTP



dGMP

Nucleotide act as dual function → provide 3'-OH group for binding of next nucleotide



pyrophosphate acts as energy for form of phosphodiester bond b/w two nucleotide.



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* Packaging of DNA

Length of DNA = no. of base pair $\times$ distance
b/w two bp.

$$= 6.6 \times 10^9 \text{ bp} \times 0.34 \times 10^{-9} \text{ m}$$

$$= 2.2 \text{ m}$$

fit in nucleus

$$\text{Nucleus dimension} = 10^{-6} \text{ m}$$

We need packaging of
DNA

• folding of DNA = packaging of DNA

→ done by protein (+ve charge amino acid)

Histone protein
(Basic)

→ main protein

→ ex: Arginine & lysine

H₂A (2)

H₂B (2)

H₃ (2)

H₄ (2)

→ octamer of
histone protein.

Non-histone protein
(acidic)

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- DNA is negatively charge and wrap around positively charge histone protein

• Chromatin & Chromosome

(DNA, histone protein, non histone protein, small amount of RNA, linear)

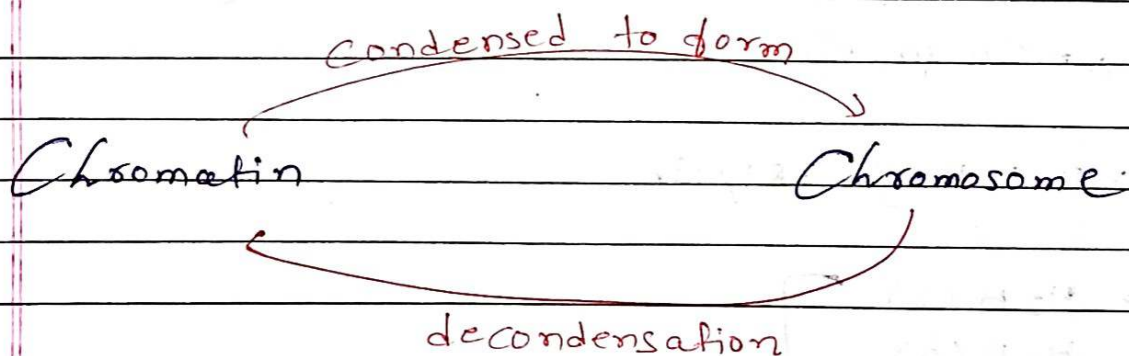


Chromatin

- ↳ less folded DNA, long, thin, less visible / indistinct, complex DNA
- ↳ In interphase / non-dividing stage of cell division

Chromosome

- ↳ more folded DNA, short, thick, more visible / distinct, simple DNA,
- ↳ In prophase, meta, anaphase (dividing stage)





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DNA

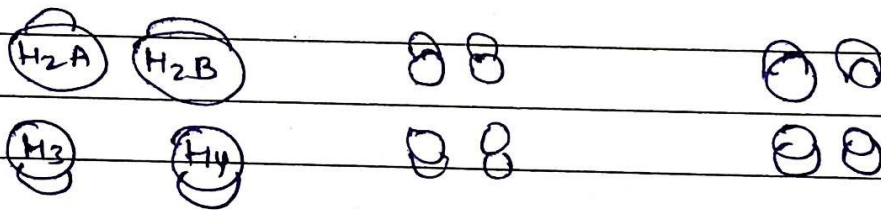


Chromatin



Chromosome

- processes of packaging



Microbes in Human Welfare

* Microbes in household product

(1) Curd

Milk (lactose)

{ Lactic acid bacteria $\rightarrow$
+ inoculum / starter (LAB)
(Lactobacillus acidophilus
bacteria)

milk (Lactic acid)

{ partially digest milk protein

Curd is formed

{ $\rightarrow$ nutritious than milk (vit B₁₂)
 $\rightarrow$ inhibit growth of other bacteria
in stomach

(2) Bread / Idli or dosa

• Bread

{ $\rightarrow$ yeast (saccharomyces cerevisiae)
or, baker's yeast
 $\rightarrow$ wheat

- Idli or dosa

- ↳ Streptococcus / Leuconostoc

- ↳ rice or black gram

- Swelling of dough (CO_2 & ethanol produced)

Swelling / puffy appearance

③ Swiss Cheese

Milk (Lactose)

↳ Lactobacillus

Milk (Lactic acid)

↳ propionibacterium shermani (bacteria)

propionic acid + CO_2

↳ Large holes are created

- Fermentation + fermentation is a biological process in which microbes produce enzymes, gases, alcohol etc.

- ↳ anaerobic process

④ Roquefort cheese

↳ penicillium roqueforti (fungus)

⑤ Toddy

↳ Caryota urens (plant)
or palm



Naturally yeast present



Fermentation (sap)



Traditionally, drink produced (Toddy)

* Microbes in industrial product

① Alcohol

by secreting Zymase



Saccharomyces cerevisiae (brewer's yeast)

is used for fermenting malted cereals & fruit juices to produce alcohol

↳ Without distillation (low alcohol) = beer, wine

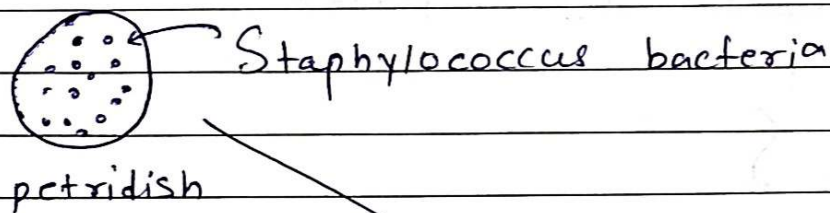
↳ With distillation (high alcohol) = Rum, Whisky

Brandy

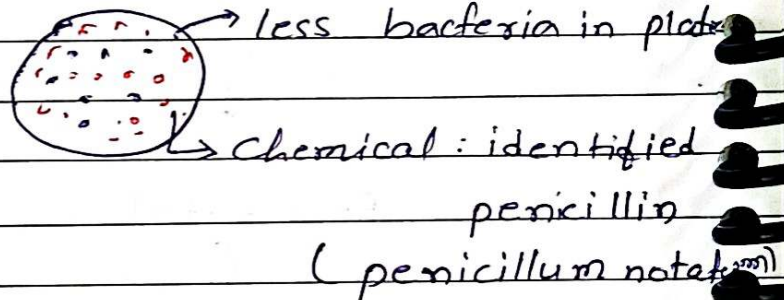
② Antibiotic

↳ Chemicals isolated from microbes and use to ^{kill} disease causing microbes

• Alexander Flemming



dustbin



• **Florey & Chain** - stated penicillin can used as antibiotic

• ~~1944~~ In 1945 Florey, Chain and Flemming awarded by noble prize.

• penicillin used during World War II for treatment of American soldier.

* Chemical, Enzyme, bioactive molecule

↳ Which active in living organism.

• Organic Acid

① Citric acid ÷ *Aspergillus niger*

② Acetic acid ÷ *Acetobacter aceti*

③ Butyric acid ÷ *Clostridium butylicum*

• Lipase

↳ used in detergent industry to remove oil stain from laundry

• Pectinase, proteinase

↳ Clarification of juice (clear)

• Streptokinase

↳ *Streptococcus bacteria*

↳ Remove clot from blood vessels (clot buster)

• Cyclosporin A (drug)

↳ *Trichoderma polysporum* (fungus)

↳ Suppress immune system during organ transplant

• Statin

↳ *Monascus purpureus* (fungus)

↳ lower blood cholesterol

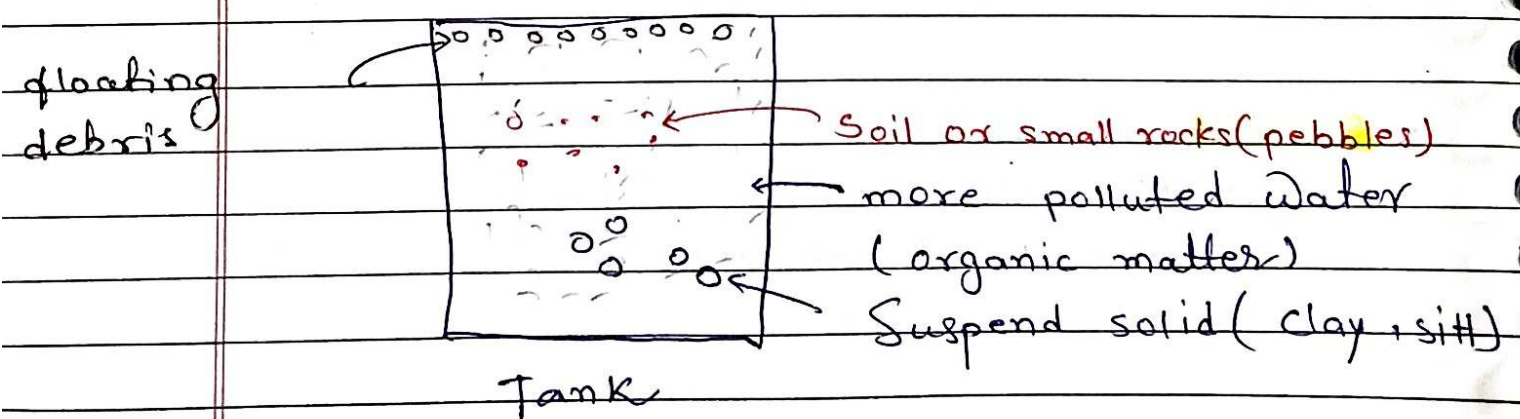
- Mevalonate substrate bind with active site of HMG co-A reductase (enzyme) than cholesterol synthesis occur. If we use Statin, it bind with ~~that~~ active site of HMG co-A and stop binding of mevalonate. So no cholesterol synthesis.

* Waste Water treatment

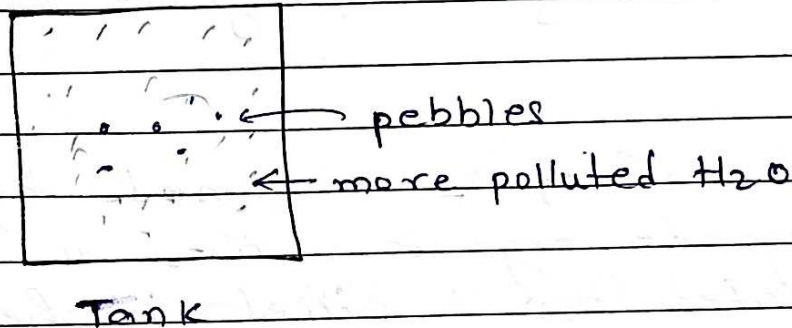
- Municipal waste H₂O/Sewage (human excreta) consist of organic matter, pathogenic micro-organism. (A more polluted)
- Municipal waste H₂O transfer in sewage treatment plant (STP). In STP degradation of organic matter occur. (waste water is less polluted), then it transfer into river

* STP

① Primary treatment/physical

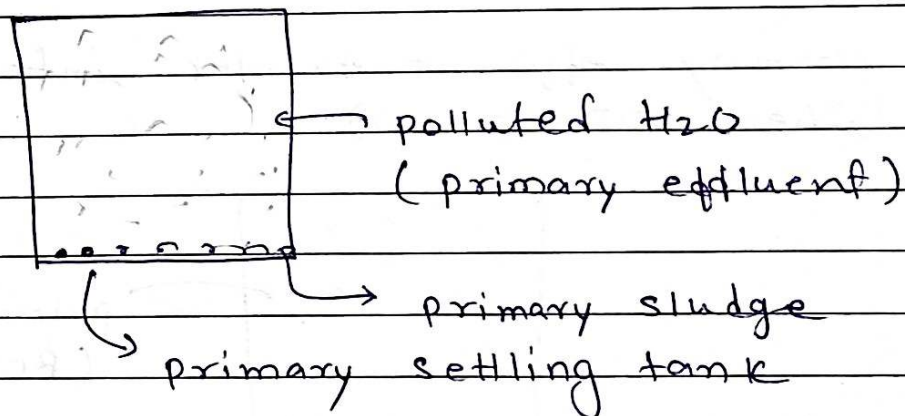


(i) Filtration → floating debris & suspended solid remove



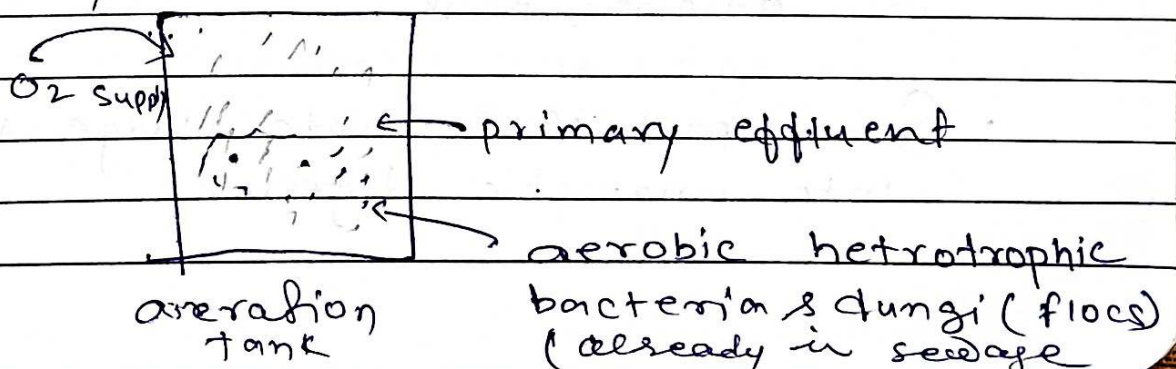
(ii) Sedimentation

↳ solid collect at bottom (alc density)

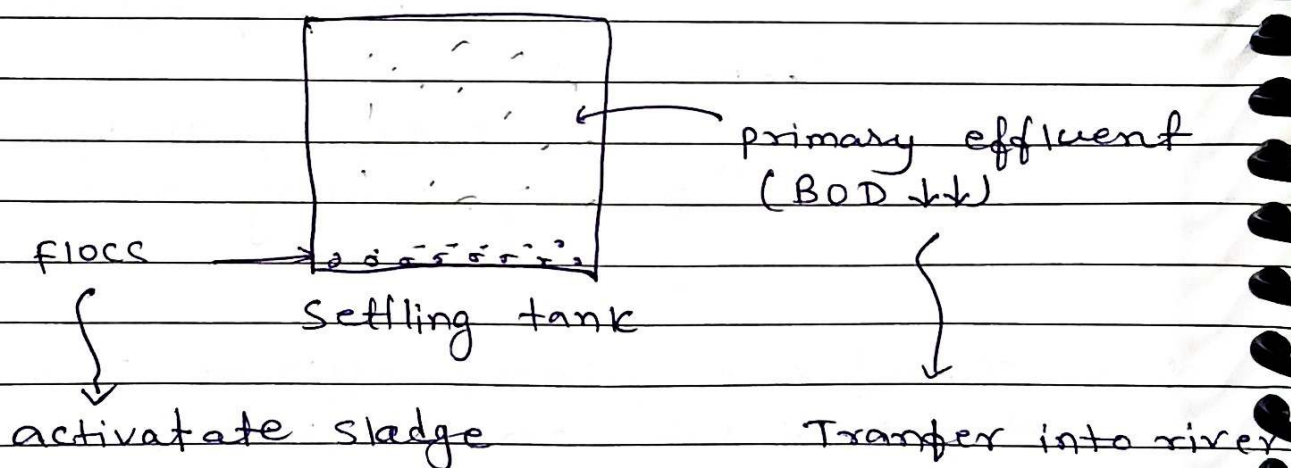


Note: Transfer of primary effluent from primary settling tank into aeration tank (for secondary treatment)

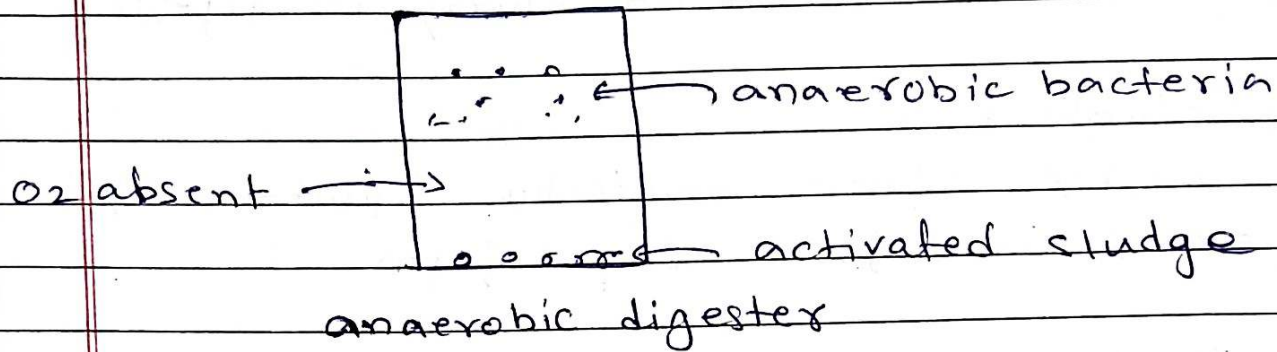
② Secondary treatment / Biological



- Due to O_2 , amount of floc increases and it degenrate/degrade organic matter of H_2O .
- Amount of O_2 consumed by flocs to degrade organic matter in 1 litre of polluted H_2O is called biochemical oxygen demand (BOD)
- primary effluent $\xrightarrow{\text{Flocs}}$ prim eff (BOD $\downarrow$)
- primary effluent transfer into settling tank (when BOD is low)

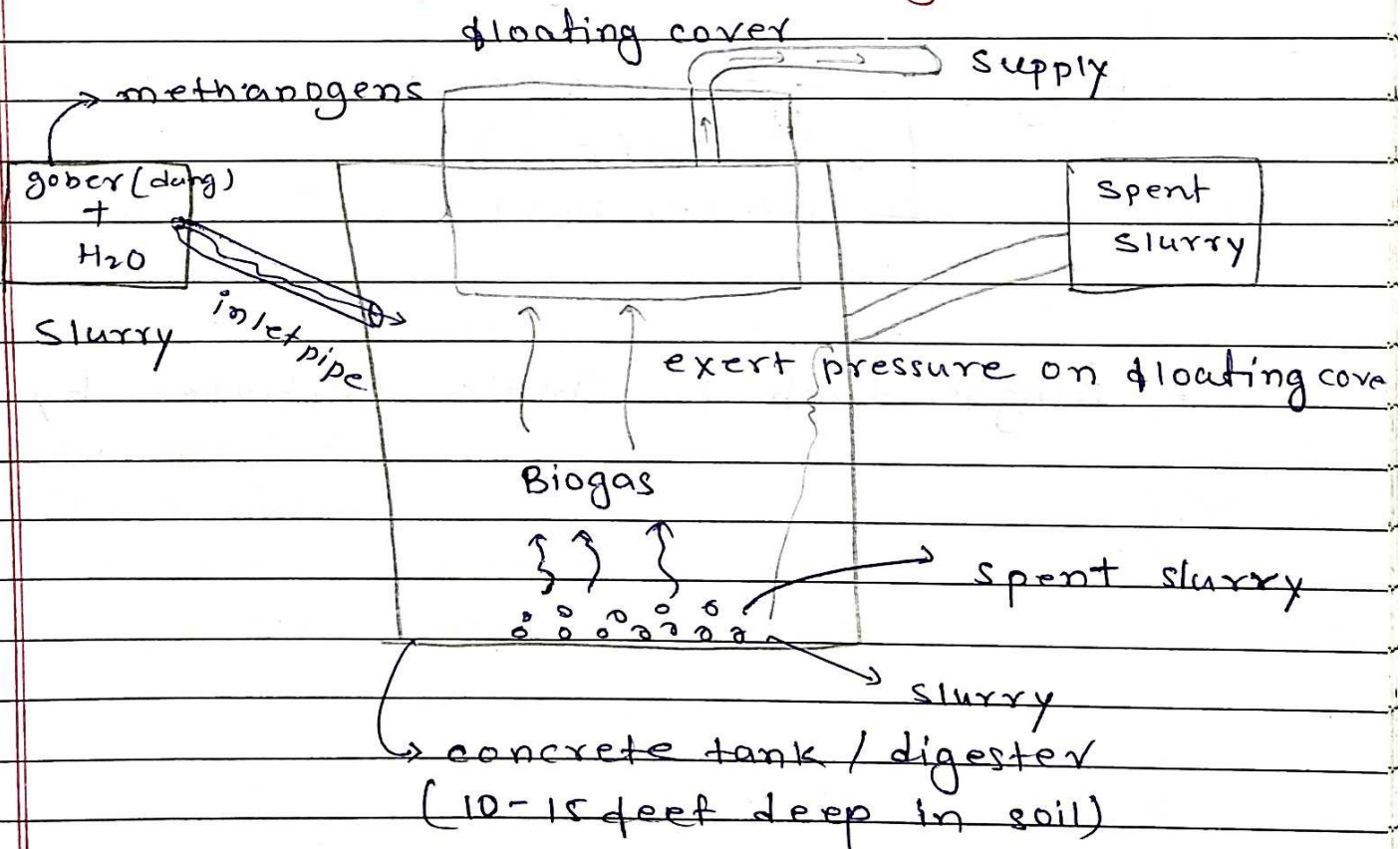


- Some part of activated sludge (Flocs) transfer into aeration tank
- Some part of activate sludge transfer into anaerobic digester.



- Anaerobic bacteria digest activated sludge and produce biogas (CH_4 , CO_2 , H_2 , H_2S)
- Ministry of environment & forest initiated 'Ganga action plan' & 'Yamuna action plan'

* Microbes in production of biogas



- Three process acts on slurry in digester

① Solubilisation

Complex cellulose, hemicellulose, protein, lipid break and form simple form

② Acidogenesis

Simple form $\longrightarrow$ acetic acid

③ Methanogenesis

acetic acid $\longrightarrow$ Biogas
 $\swarrow$
 methanobacterium (anaerobe)
 (methanogens)

Biogas $\longrightarrow$ $\approx$ 50-70% (CH_4)
 $\searrow$ 30-40% (CO_2)
 $\searrow$ 10% ($\text{H}_2, \text{H}_2\text{S}$)

- Biogas tech in India initiated by

* Microbes as a biofertilizer

↳ Azolla (ex)

- Insecticide & pesticides
 - pollution
 - Soil fertility decrease
 - enter in crop
 - no discriminate b/w target and non-target organ
 - It completely kill target (insect/prest). predator depend upon that insect also removed.

So, better shift toward organic farming. Where we use bacteria, blue green algae and fungi (which is biofertilizer)

① Bacteria

- Rhizobium: Root of legumes
- Frankia: Root of non-legumes (alnus, casuarina plant)

Both are symbiotic, help in N_2 fixⁿ.

(iii) Azotobacter

Azospirillum

Rhizobium

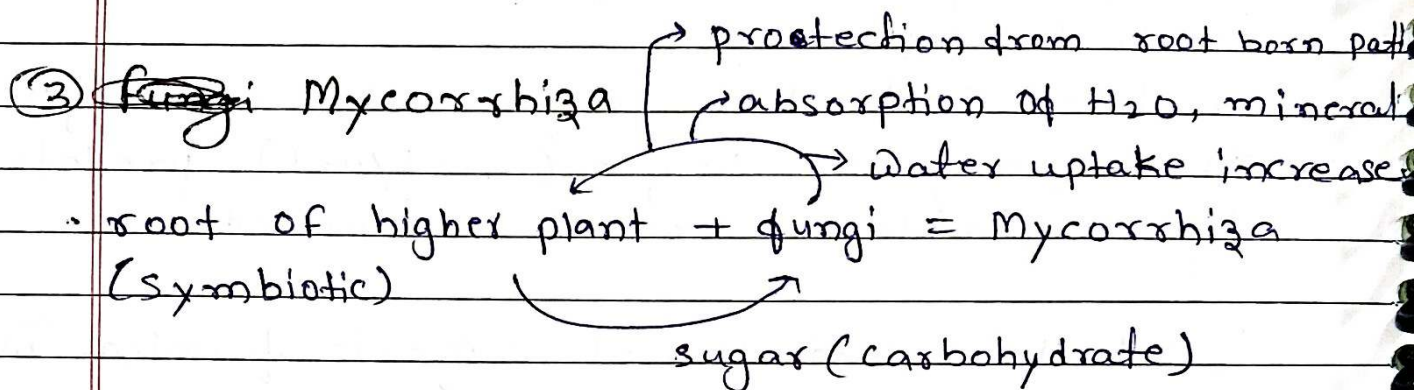
Beijerinckia

free living in soil

help in N_2 fixⁿ

② Blue green algae

- Nostoc, anabaena, Oscillatoria
- Use in rice/paddy field
- Help in N_2 fixn



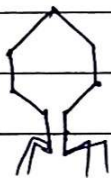
- In mycorrhiza, fungi generally belong to genus Glomus

* Shape of bacteria

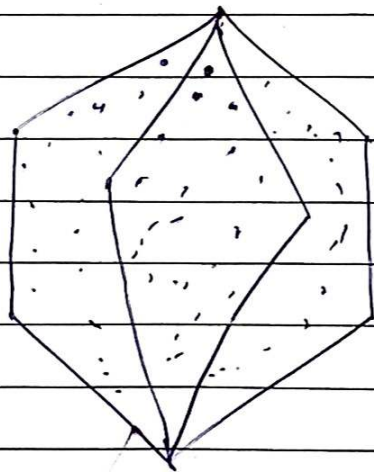
- (i) Coccus (spherical)
- (ii) Bacillus (Rod shape)
- (iii) Spirillum (Spiral shape)
- (iv) Vibrio (comma shape)

* Virus

- ① Bacteriophage



- ② Adenovirus (cause respiratory infection)



- ③ TMV (Tobacco Mosaic Virus)
↳ rod-shaped



Tissue Culture

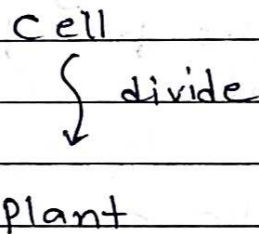
* Tissue culture

When plant cell/tissue/organ grown in culture or nutrient medium, then ~~this~~ it is able to form complete plant and this technique is called tissue culture.

- Nutrient medium consist of plant hormone (auxin, cytokinin), inorganic salt, carbon source (sugar), vitamin, amino acid etc.

Q. Why cell convert into a plant?

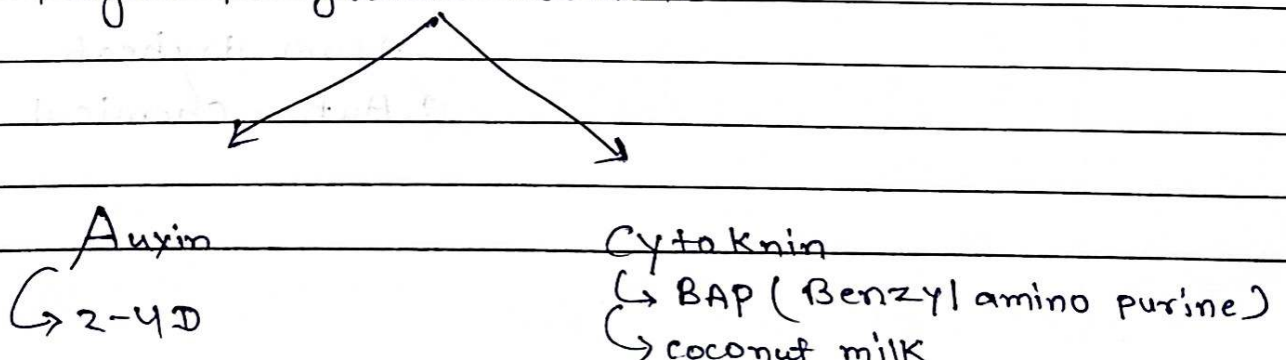
→ Because plant has totipotency condition (ability to form plant by cell)



* Condition for tissue culture

① Nutrient media (pH = 5.6 - 5.9)

- Carbon source (sucrose), vitamin, amino acid, inorganic salt, agar, growth hormone



- Both hormone help in cell division.
- Auxin (2,4-Dichloro phenoxy acetic acid)
↳ Root formation
- Cytokinin
↳ Shoot formation

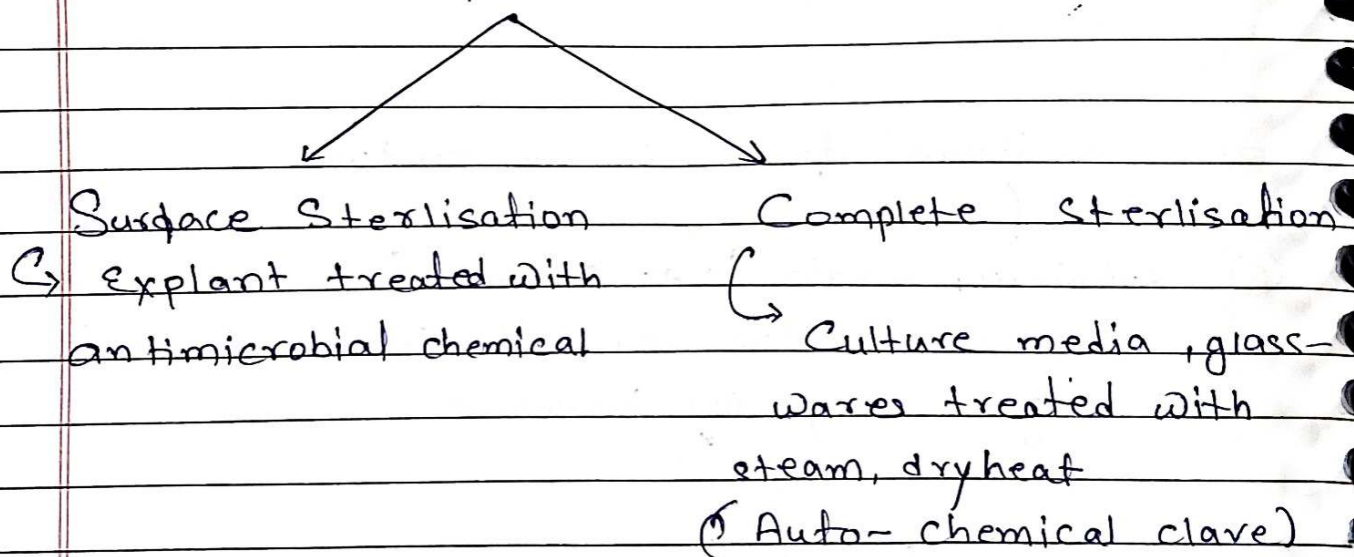
② Explant

- Any part of plant used in Tissue Culture is called Explant (ex: root, leaf)

③ Aseptic condition

- ↳ Explant Culture media, glasswares (Beaker, Flask, test-tube) should be free from pathogen.
(completely sterilised)

Aseptic condition (sterilised condition)

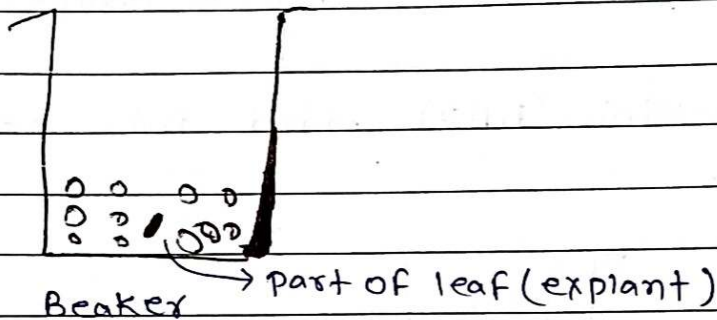


④ proper aeration (O_2)

↳ for growth.

* ~~Pecking~~ Technique (callus culture)

↳ solid nutrient media



(Nutrient media)

(sterilised)

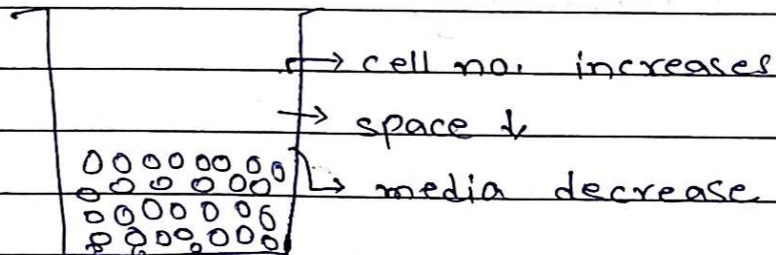


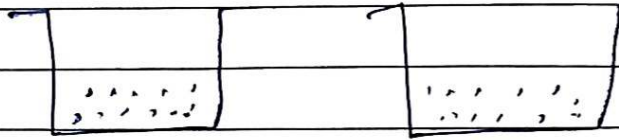
solid

(agar-agar)

↳ solidifying agent

- Explant starts dividing form a mass of cells called Callus.

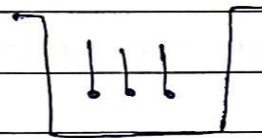




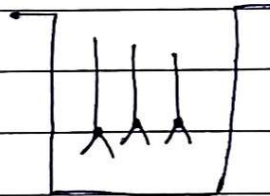
new beaker (fresh media)

Transfer of cells from main beaker to newly fresh media beaker, this is called Subculturing

- Now cytokinin (BAP) added into beaker (shoot formation).



- Now Auxin (2,4-D) added (root formation)

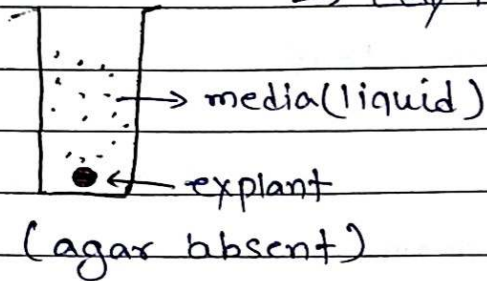


New plants (plantlets)

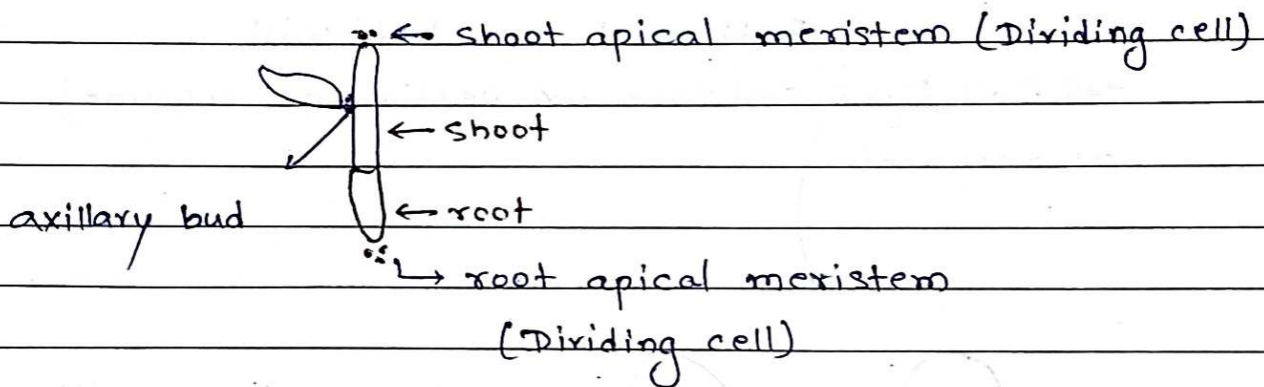
- plantlets transfer from lab to soil (environment) (Hardening)

* Suspension Culture

↳ cell/tissue grow in liquid medium



* Meristem Culture (virus-free culture)



- Rate of division is ~~fast~~ of root/shoot apical meristem is fast, So virus is not able to grow at meristem

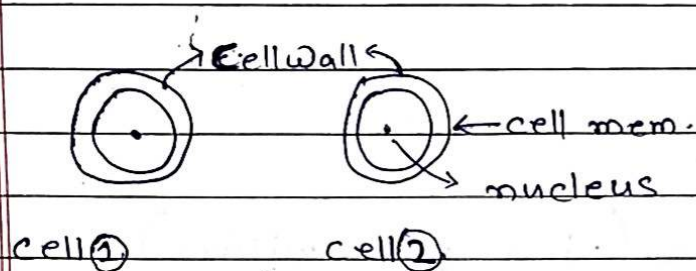
Meristematic cell grow in culture media



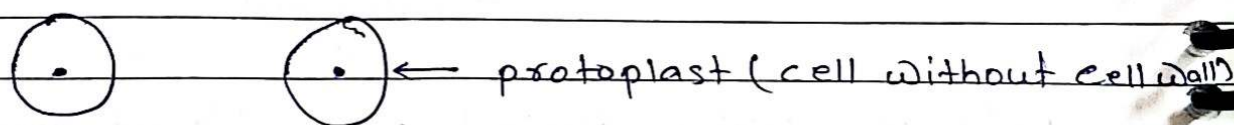
New plant formed

* Somatic Hybridisation (protoplast fusion)

Somatic cells $\div$ root, stem, leaf



Both cell treated with
cell wall digest cellulose or pectinase (enzyme)
or removed

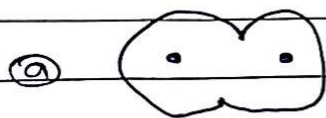


fusion of protoplasts

① Electric current (electrofusion)

② chemical (chemofusion)

↳ polye

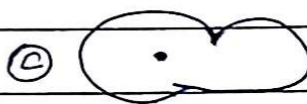


Both nucleus unfused! Hetrokaryon



Synkaryon

Both nucleus are fused



one nucleus
cybrid degenerate

e.g. of somatic hybridisation

First: Tobacco

↳ Two different species

• Pomato

↳ potato + Tomato

↳ it doesn't contain all character of potato & tomato

• Bomato

↳ Brinjal + Tomato

~~S~~ Somaclone

Organisms and Population

* Introduction

- Individual of same species is called population (which interbreed together)
- Collection of different population is called Community.

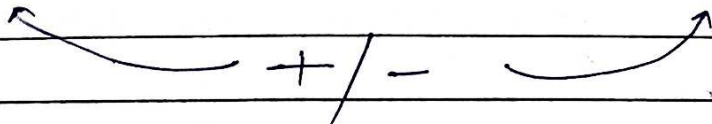
* Population interaction

Interaction b/w organisms of same species (intra^{specific}-interaction) or different species (inter-specific) is called population interaction.

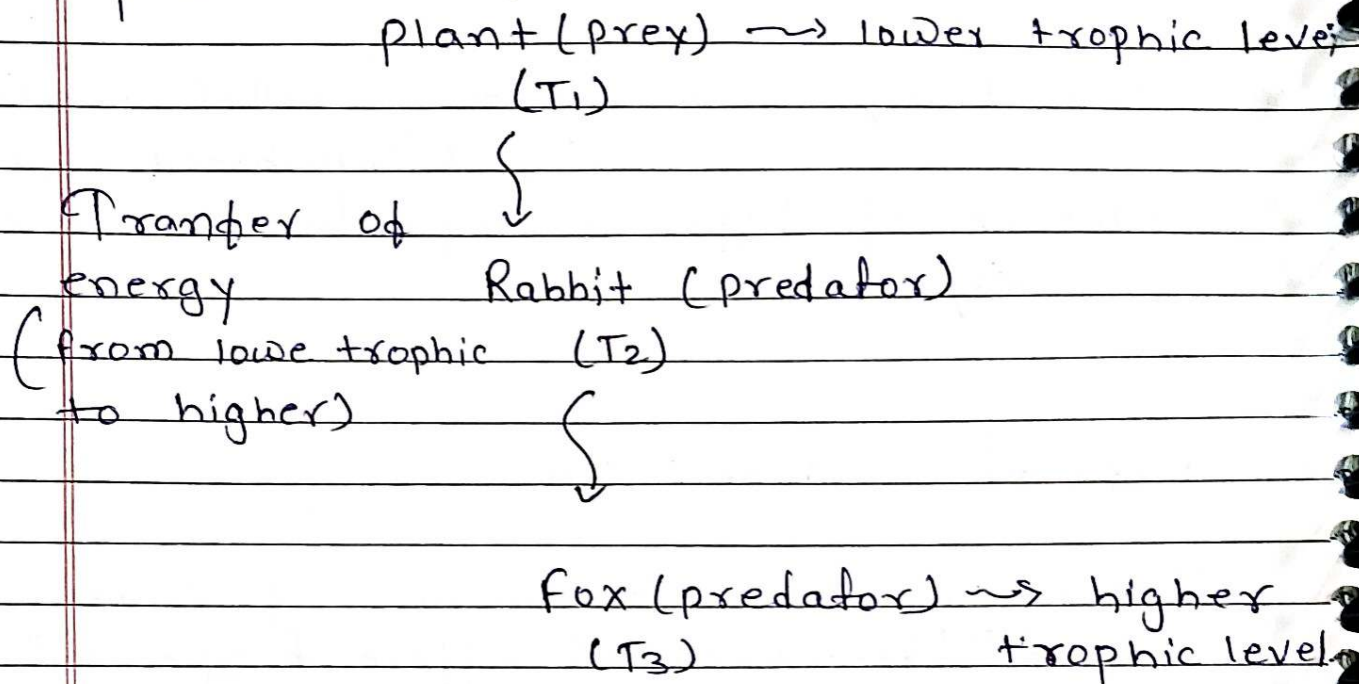
* Predation (inter-specific interaction)

Concept ①

Deer $\xrightarrow{\text{Feed}}$ tiger
seed $\xrightarrow{\text{Feed}}$ sparrow
plant $\longrightarrow$ herbivores
(prey) (predator)

Species A (predator)	Species B (prey)
→ Beneficial (positive)	→ Detrimental negative (harmful)
	

Concept ② Role of predator



- If predator is absent, Ecosystem become unstable.
- predator act as conduit (channel / pipeline) of ecosystem.

Concept ③ Prudent predator (cleaver)

- predator never kills all prey, otherwise it will also disappear because predator won't get food. So it keeps the population under control / minimise the prey population.

Concept ④ Exotic/alien species (prey)

prickly pear cactus (prey) (opuntia)



introduced in Australia



At that time its predator was absent



So it create disturbance



~~Later~~ Later insect/moth (predator) feed on opuntia



population under control

Concept ⑤ Biological control agent (biocontrol)



act as predator

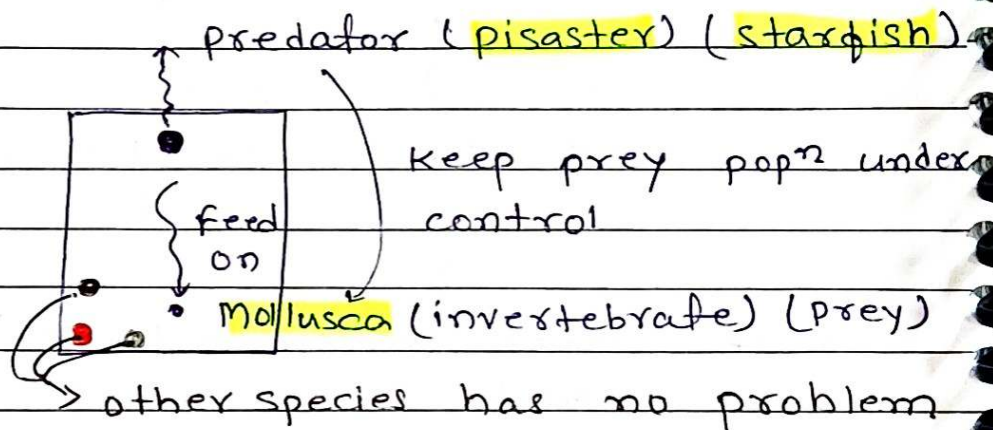
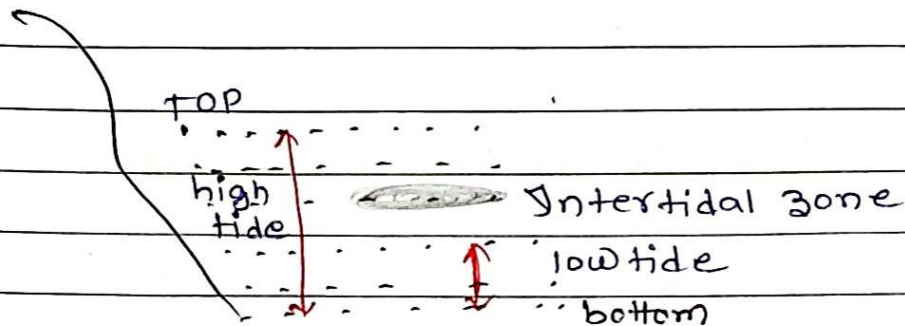


feed on insect/prey



So dependance on insecticides/pesticides reduced.

Concept 6 Rocky intertidal zone (American pacific coast)



- If experimentally predator removed



so populⁿ of invertebrate increase



so fight starts with other species (interspecific)



Species of invertebrate extinct

Concept 7) Cryptic colouration

→ Organisms change their body colour & show resemblance with background. So not detected by predator

Concept 8) Mimicry: Batesian Monarch butterfly

Caterpillar larva → feed on calotropis
 ↳ Toxic chemical cardiac glycoside enter into larva

Adult Butterfly
 (Toxic chemical)

Bird/ predator

→ reduced feeding efficiency
 → Reproductive capacity (affected)
 → Death

Concept 9) 25% insect feed on plant (phytophagous)

Morphological
 defense

→ Thorn in acacia,
 cactus

(protection from
 herbivores)

Chemical defense

→ Cardiac glycosides (Toxic)



Calotropis plant

Caffeine,
Opium
Nicotine etc } → Act as defense

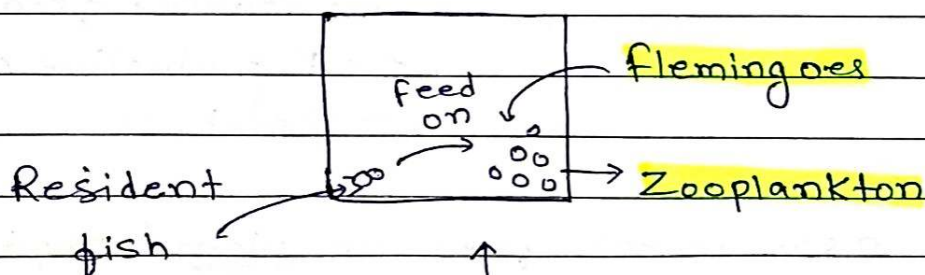
* Competition (-/-)

Concept (1)

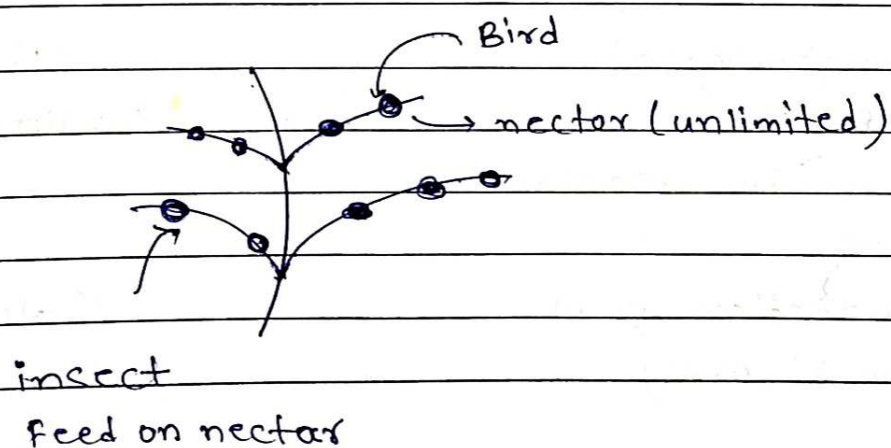
Generally we believe competition occur only
(i) In related species
(ii) When food is limited } → but it is not true

Concept (2)

• South American Lakes



→ Competition in unrelated species.



- Feeding efficiency of insect (one species) is reduced in presence of other species (bird) [interference competition]

Concept (3)

Note: Fitness of organism can be measured in terms of ' r ' (intrinsic rate of natural increase / biotic potential)

' r ' value ~~more~~ high $\rightarrow$ more fit

' r ' value less $\rightarrow$ less fit

r = Tendency of organism to produce maximum offspring under fav condⁿ.

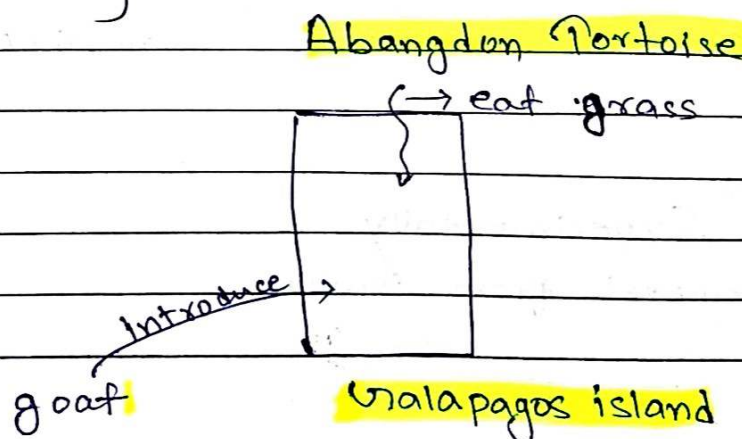
Concept (4) Types of competition

- (1) Competitive exclusion
- (2) Competitive co-existence

(1) Competitive exclusion

- No Two organism can live together if they have same ecological niche (Gause principle)
- If they live together, then superior one will eliminate/exclude other species (inferior) [comp. - exclusion]

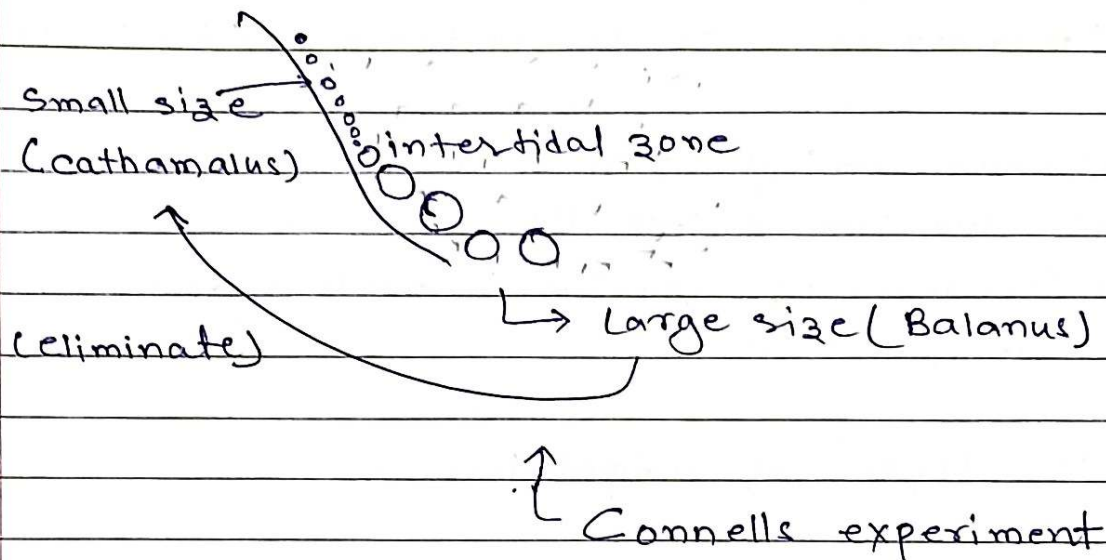
e.g



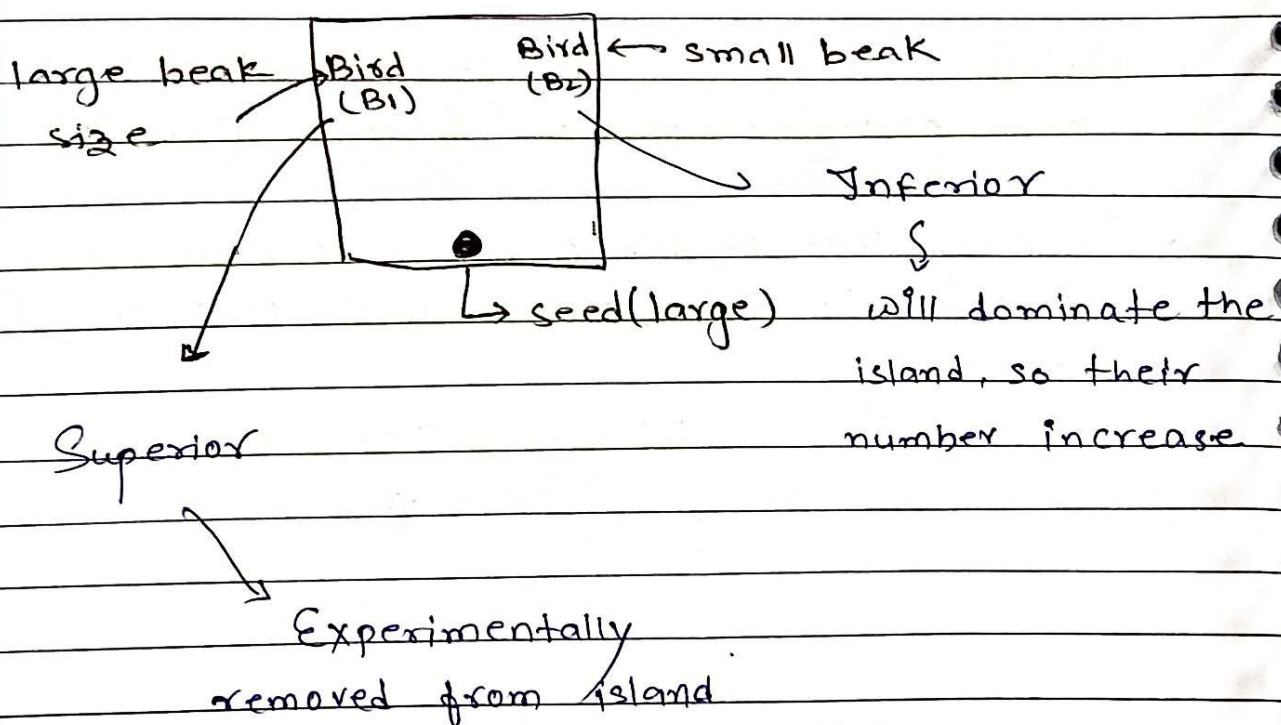
Goat is better browser than Tortoise, so Tortoise excluded

invertebrate

Rocky coast of Scotland (Barnacles)



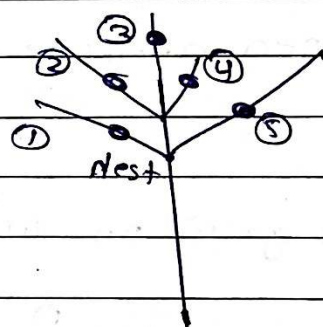
Concept ② Competition Release



Concept ⑥ Competitive co-existence

- Closely related species can live together, don't kill each other.

Mac Arthur study 5 closely related species of warblers (birds) staying on same tree.



→ feed on insect on diff. branch.

→ nest and on diff. branch.

→ foraging pattern (feeding time diff.)

Resource partitioning ✓

Changes in environment → will affect producer directly

↑ depend

Herbivores

↑

Carnivores

* Commensalism (+/0)

Species A: Benefit(+) Species: neither harm nor benefit (0)

eg. (i) Barnacles (invertebrate) present on whale
 → free ride, shelter

(ii) Tentacles of sea anemone protect Clownfish from enemies.

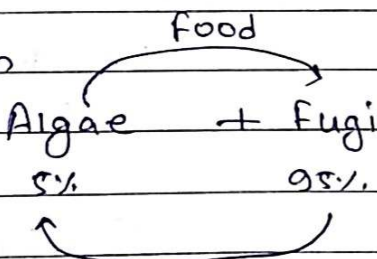
(iii) Epiphyte (orchid) grow on Mango for support

(iv) Cattle egret bird & Cattle
 → difficult to locate insect, so when cattle eat grass, then insect comes outside so better to locate

* Mutualism/ Symbiosis (+/+)

Both organism live together (Benefitted)
 can't live without each other (Obligatory/mandatory)

eg. (i) Lichen



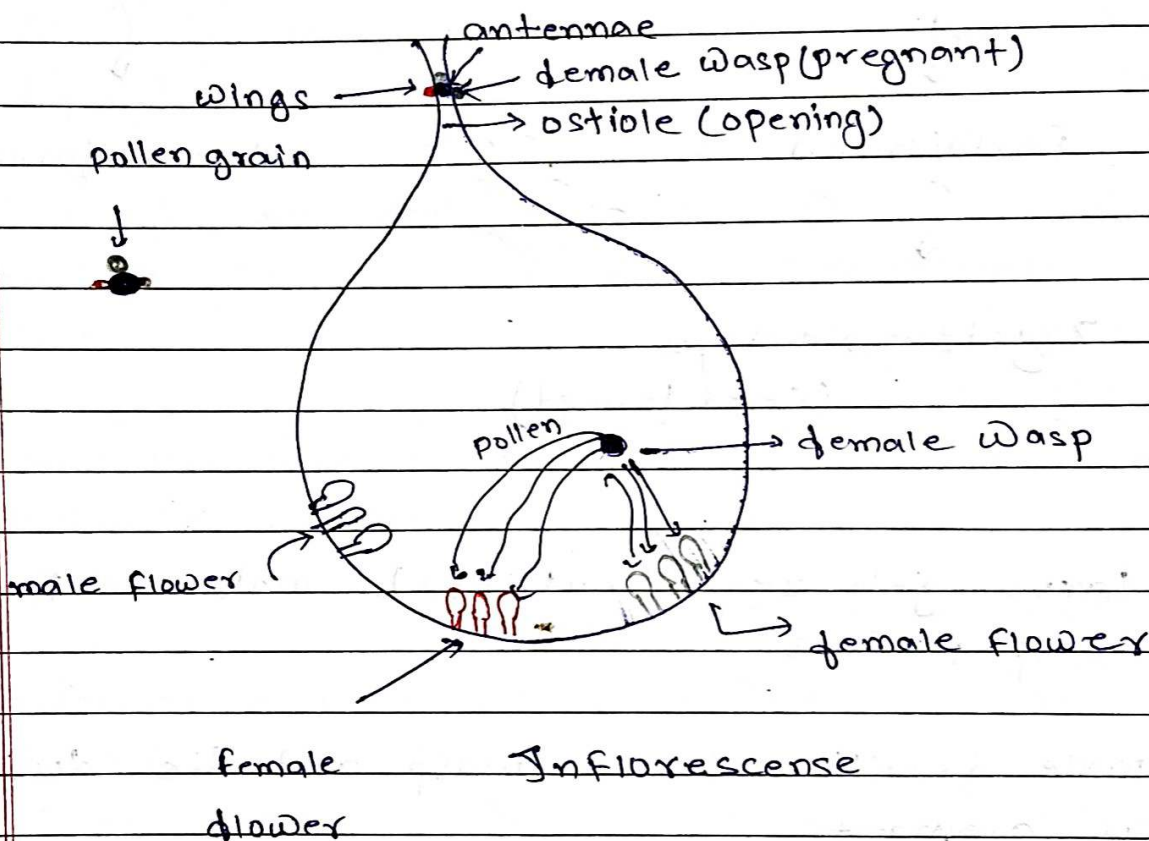
The diagram shows two boxes: 'Algae 5%' on the left and 'Fungi 95%' on the right. A curved arrow labeled 'Food' points from the Algae box to the Fungi box. Another curved arrow points from the Fungi box back to the Algae box, with the text 'shelter, absorption of H₂O & minerals' written below it.

shelter, absorption of H₂O & minerals

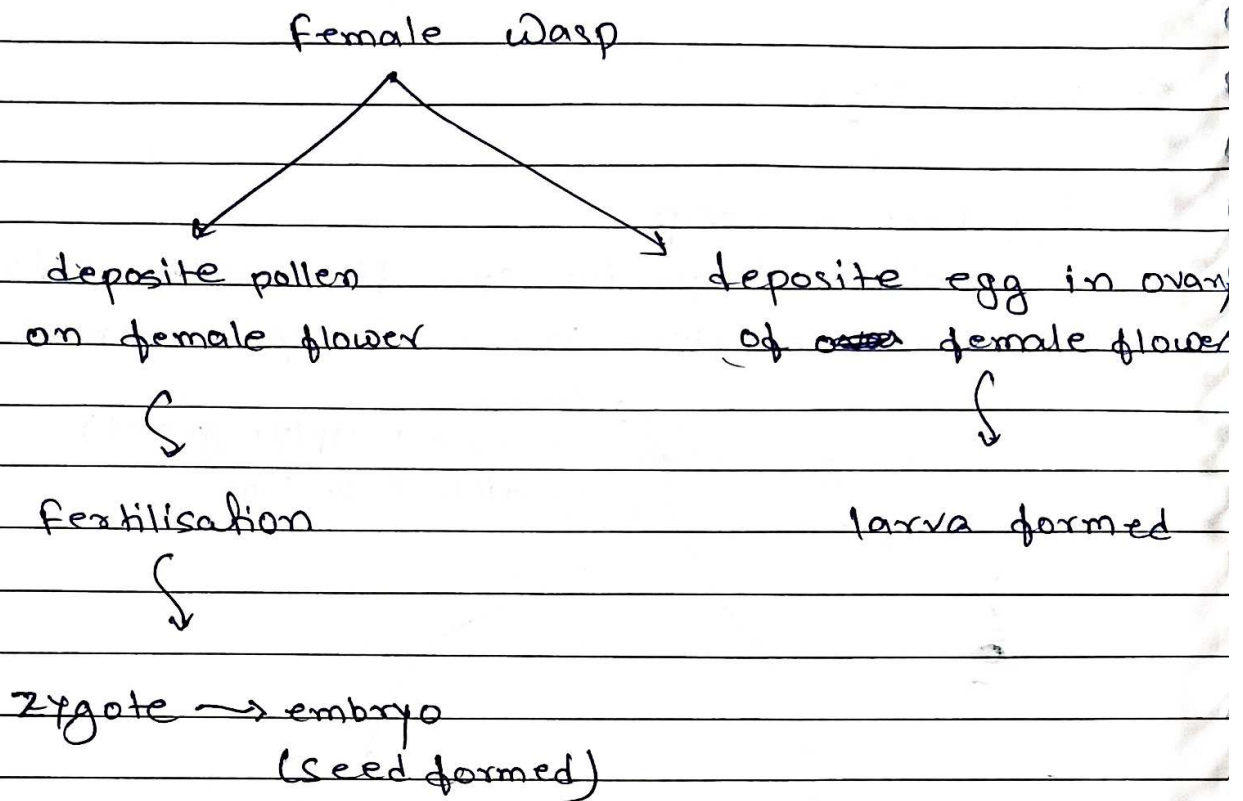
② Mycorrhiza

③ fig tree & wasp

- ~~Specific~~ species specific relationship.
- Both can't complete their life cycle without each other.



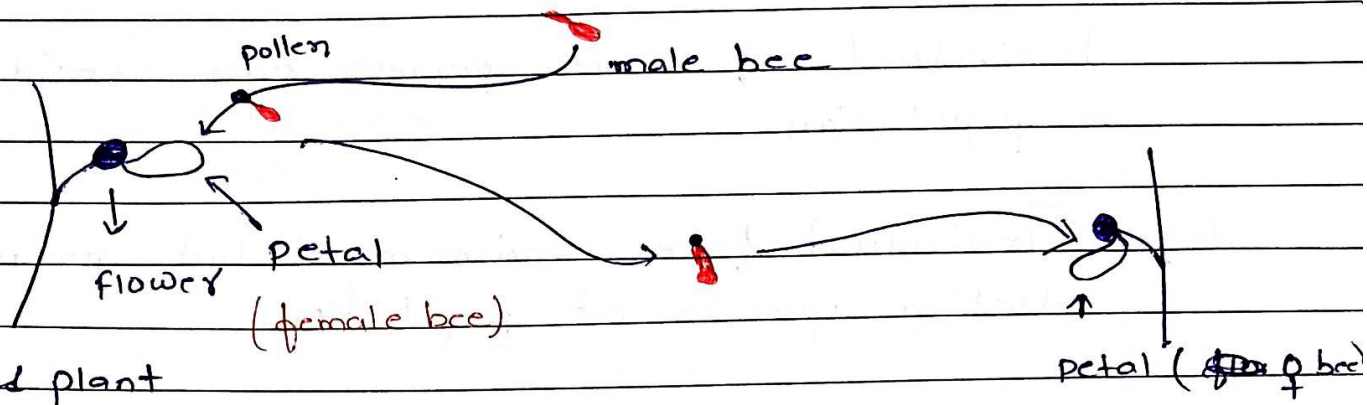
- Female wasp (pregnant) carry pollen grain comes from different fig tree enter into fig inflorescence through ostiole (small opening). Wings and antennae break/damage at enter.



larva gets seed (nutrition). male and female wasp produce.

- male fertilise female wasp and die. now ♀ is pregnant.
- female wasp carry pollen while moving outside the fruit and enter into another fig

(c) Ophrys (orchid) & bee



- One of the petal of orchid flower modified in such a way that it shows resemblance with ♀ bee.
- male bee consider petal as female bee & visit orchid flower in order to copulate but it is pseudocopulation.
- pollen grain shed on male bee, and this bee visit another orchid flower & release pollen on stigma.
- **Coevolution**: if female bee ~~evolved~~ evolved in structure & form, then petal of orchid have to evolve to complete resemblance with ♀ bee, Otherwise male bee won't come so no pollination.

* Population

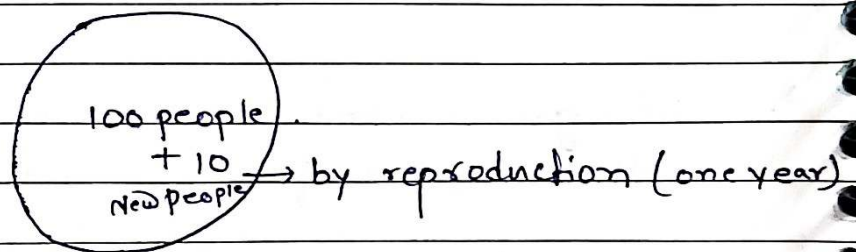
Individual of same species can consider as a population.

Note: Individual face environment but natural selection operate at population.

* Birth rate & Death rate & Sex ratio

• Birth rate

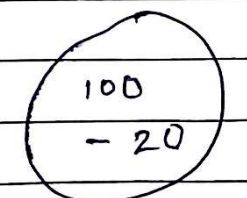
→ No. of born individual in a particular time and area by original population.



$$B.R = \frac{10}{100} = 0.1 \text{ per individual/per year}$$

• Death rate

No. of death individual in a particular time and area by original population



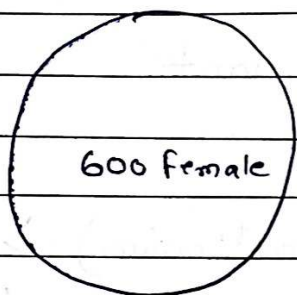
$$D.R = \frac{20}{100} = \frac{1}{5}$$

$$= 0.2 / \text{per year}$$

• Sex ratio

No. of $\delta/\phi \times 100$

Total population



1000 individual

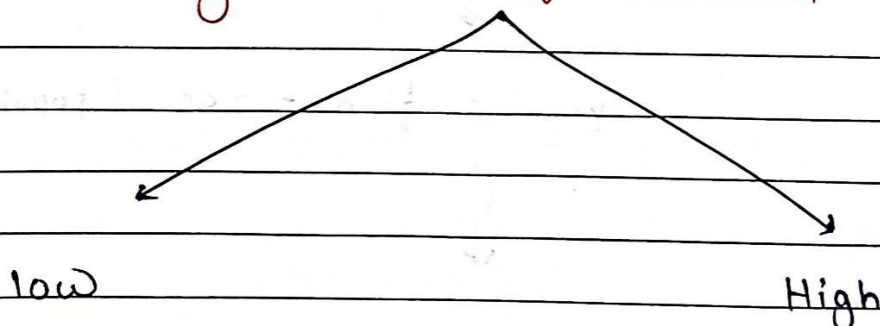
$$\frac{600 \times 100}{1000} = 60\% \phi$$

* Population size/density

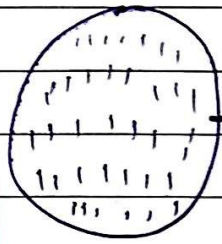
→ No. of individual in a particular area in particular time.

method

① By counting the no. of individual (Best method)



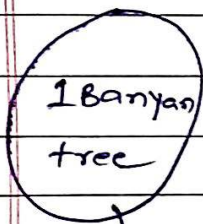
- ② Sometime to calculate the population density by counting is not best (No. ~~of~~ is meaningless)



→ 200 parthenium plant

area

population-density (parthenium) > pop den (Banyan)



1 Banyan tree

Biomass of huge Banyan is more compare to parthenium.

→ more impact on environment

③ Relative density

⇒

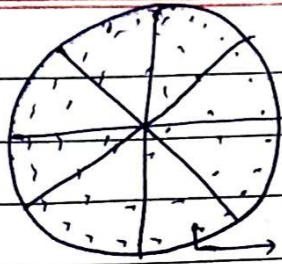
Net (1000 fish)



specific fish = 200 (population density)



$$\text{Relative density} = \frac{200}{1000} \times 100 = 20\%$$



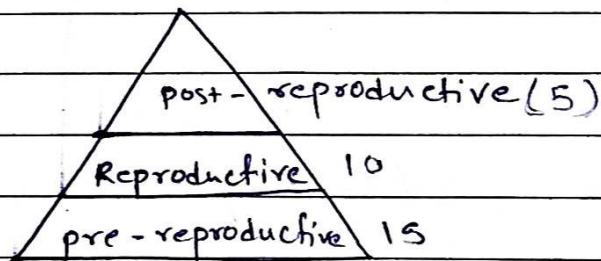
$$\text{Total} = 300 \times 8 = 2400$$

⑤ Pug marks & faecal matter

* Age pyramid

→ Graphical representation of individual of different ages in population

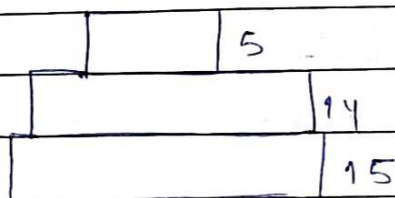
(1) Triangular/expanding



→ No. of individual of pre-reproductive is more than reproductive.

→ population size/density expand/increase.

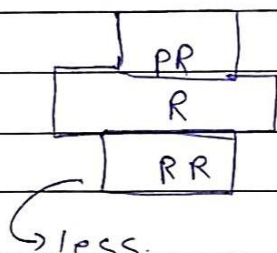
(2) Stable/Bell shaped.



→ No. of individual of pre-reproductive is marginally greater than reproductive.

→ stable population

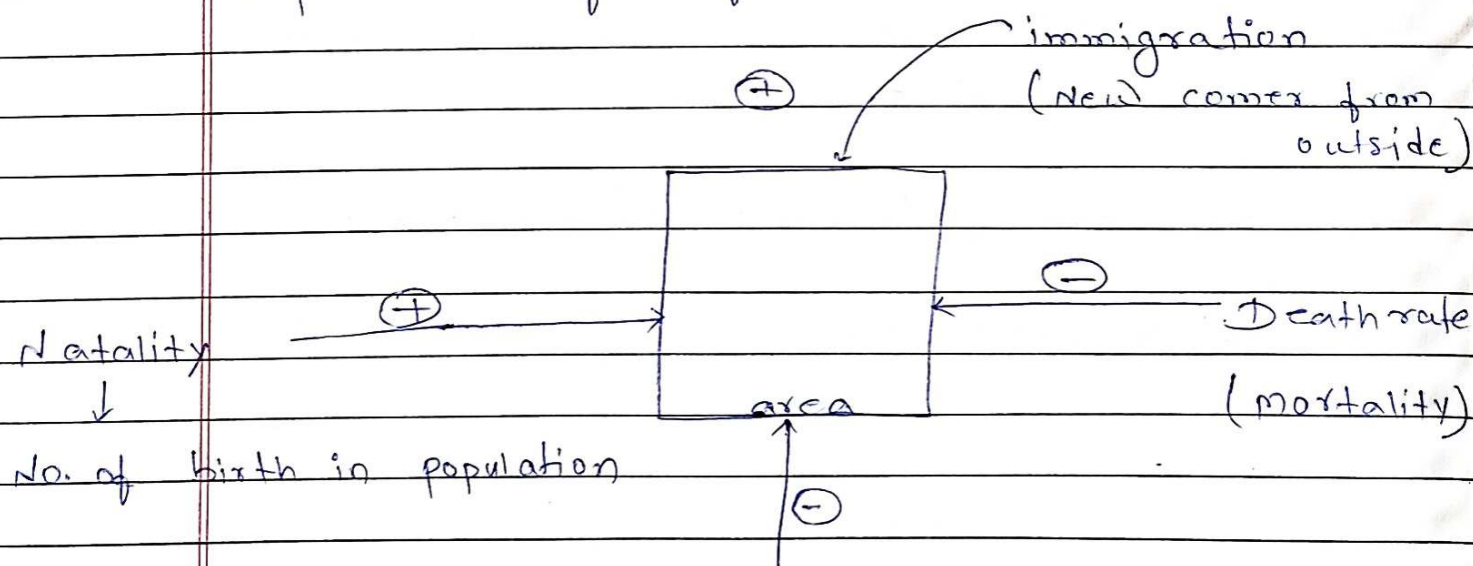
(3)



→ Urn shape/declining

* population size/density

→ depends on four factor



Emigration (No. of individual move out from area)

(2 years)

$$N_t + H = N_t + [(B + I) - (D + E)]$$



After certain
time



current population

B: birth

I: immigration

D: death

E: emigration

ex: $N_t = 200$ in 2 years $B = 10$, $I = 10$, $D = 5$
 $E = 10$, population size after two years

$$N = 200 + [(10 + 10) - (5 + 10)]$$

$$= 200 + 20 - 15 = \underline{\underline{205}}$$

- In newly formed colony/area, if you want to increase population density the immigration is best method

* Growth Model

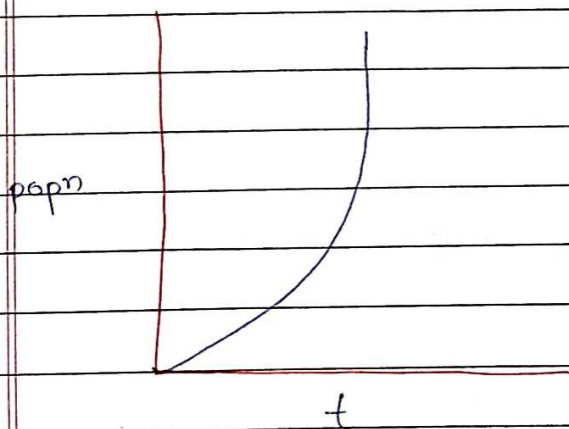
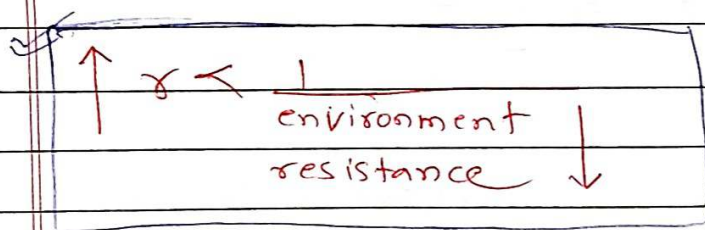
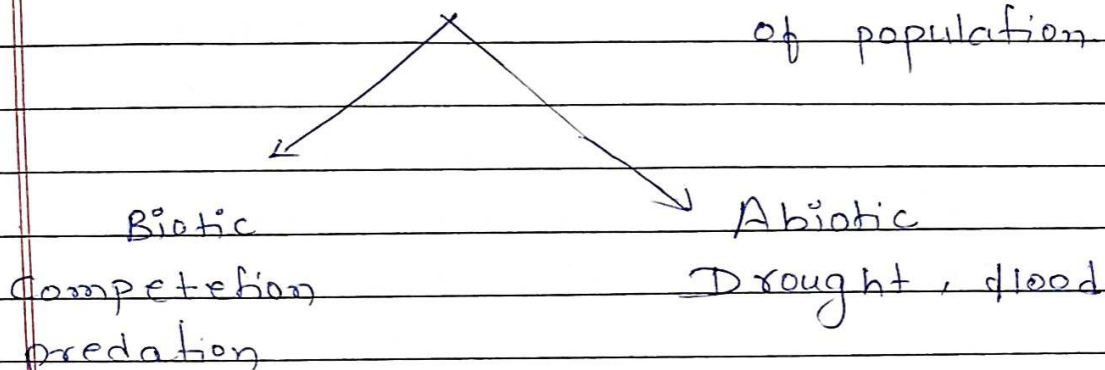
① Exponential growth/J shape curve

- Resource: Unlimited food, space
- No competition & predation
- favourable condition
- Actually not realistic
- Biotic potential:
 - ↳ maximum no. of offspring produce by individ in fav. condition

- No parental care, short life span
- r : biotic potential / intrinsic rate of natural increase

→ absent in exponential growth

- Environment resistance - which limit the size of population



it tells population rate

$$\left[\frac{dN}{dt} = rN \quad (r = b - d) \right], \quad \left(\frac{dN}{dt} \right) = (b - d) \underset{\downarrow}{N}$$

With respect of time.

actual individual?

This is differential equation, it doesn't tell current population size/density of area.

- To know the current population density, you have to integrate. $\frac{d(N)}{dt} = rN$

$$\Rightarrow N_t = N_0 e^{rt}$$

② Logistic growth

- Limited food, resource, space
- competition, predation; abiotic factors (flood etc)
- Unfavourable condition
- More environmental resistance

Carrying capacity (K)

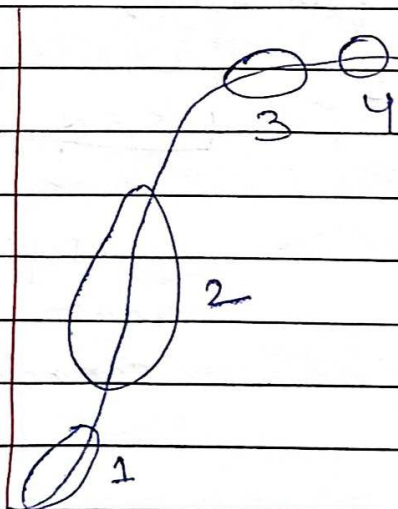
↳ no. of individuals can sustain in particular area, time as per available source.

→ less population size

→ Better parental care

• less no. offspring, realistic

• S-shap / sigmoid graph.



① Lag phase

↳ slow growth (newly habitat: you have to adapt)

② positive - Acceleration

↳ No. of individual increase.

③ Negative deceleration

↳ shortage of food, space

④ Asymptote/ carrying capacity

↳ No. of individuals left/surviving currently as per source available

$$\frac{dN}{dt} = rN \left(\frac{K-N}{K} \right)$$

N: ↑, move closer to carrying capacity

K: 20 individual (carrying capacity)

N: 12 (current population)

→ Become 20

$$K = N$$



population size reach at carrying capacity

* Parasitism (+/-)

Species A: Benefit (parasite)

B: Harm (Host)

• Adaptation in parasite

- loss of sensory organ
- loss of digestive system
- gain of adhesive structure (sucker) (help in attachment)
- High reproductive capacity to increase their pop.

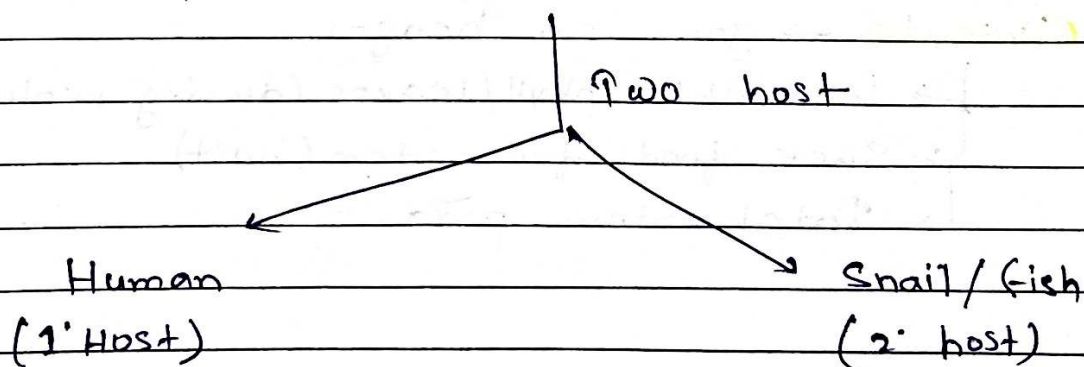
• Impact on Host

- Host become weak so killed by another predator
- Low reproductive capacity.

• Some parasite have only one host (specific host)

• If host evolve in order to get protection from parasite then parasite will have to evolve to counteract/adapt those changes otherwise its survival is not possible.

• Some parasite (liver fluke): Trematode



- Parasitism found in bacteria, fungi, plants, vertebrates and invertebrates.

- Why nature didn't select harmless parasite for host.

→ because harmful parasites favours evolution

- Types of parasite

(1) Ectoparasite → Simple life cycle
↳ present on surface of host

(2) Endoparasite

↳ present inside the host (liver, gut)
↳ complex life cycle
↳ simple morphological & anatomical structure

Ectoparasite

↳ Lice on human, Tick on dog, copepods on marine fish

↳ Cuscuta → grow on hedges

↳ loss chlorophyll/leaves (during evolution)
↳ Suck food from stem (host)
↳ Total stem parasite

Ecosystem

* Ecosystem

→ Interaction b/w biotic & abiotic component

• Types of Ecosystem

① Terrestrial Ecosystem

→ forest, grassland, Desert

② Aquatic Ecosystem

→ River, pond, ocean, lake, Estuaries (river enter into sea), Wetlands (area saturated with water)

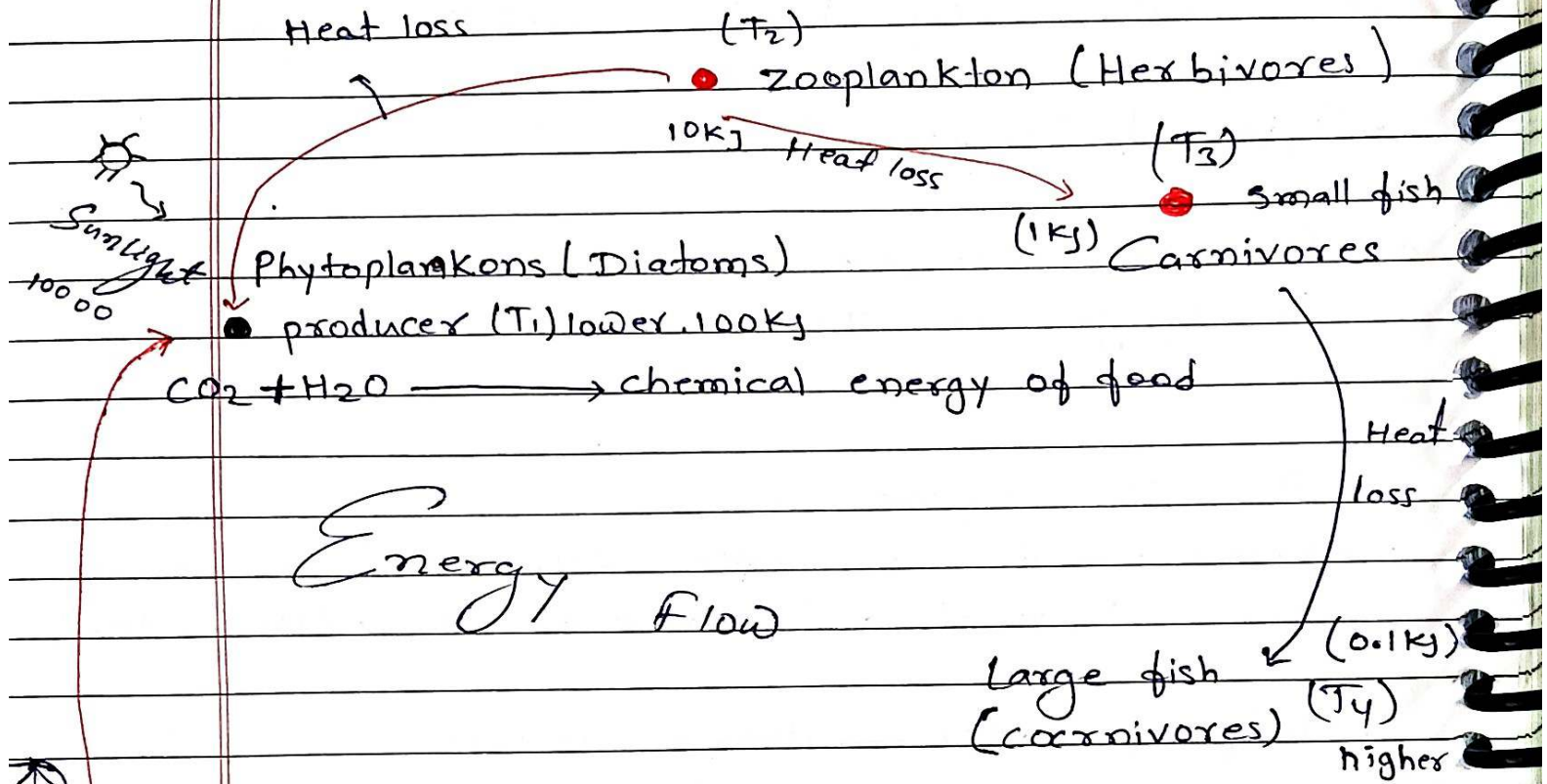
• Drop of water → Non-ecosystem

• Artificial/man-made/Anthropogenic Ecosystem

→ Aquarium, crop field/ Agriculture

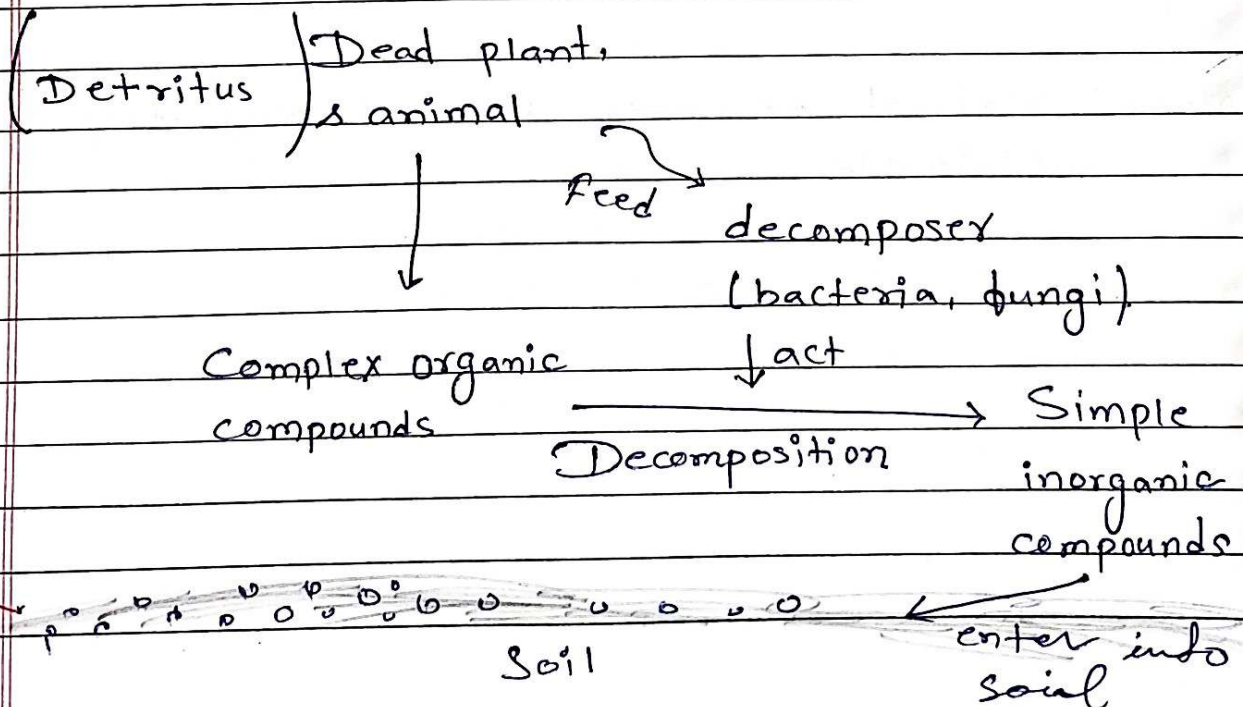
Note :- Natural ecosystem is self regulatory & self-sustainable

* Pond Ecosystem



- Food/organic matter/energy synthesis by plant during photosynthesis is called productivity

Recycling of Nutrients



- Producers include ÷ phytoplankton, algae.
Submerged plant, floating plant, edge of pond.

• Functional aspects of ecosystem

- ① Productivity
- ② Energy flow
- ③ Decomposition
- ④ Nutrient Recycling

• Structural aspect of ecosystem

* Productivity

① Primary productivity

↳ ④ Gross primary productivity (Gpp)

→ Total food/energy/organic matter (biomass) synthesis by plant during photosynthesis in particular area in particular time

⑤ Net primary productivity (Npp)

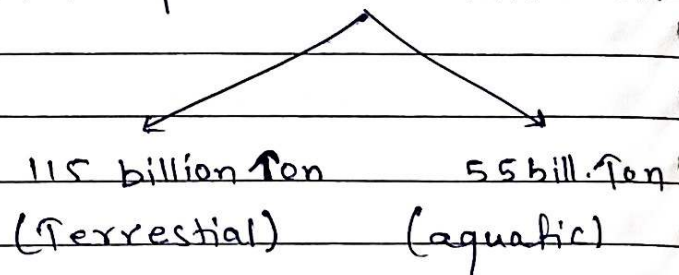
→ Energy available at plant after respiratory loss (R)

$$\rightarrow Gpp - R = Npp$$

③ Secondary productivity

→ Energy synthesis/organic matter gain by - consumers by using Npp

Note: ① Total productivity in Biosphere: 170 Billion Ton



(ii) No light in bottom of ocean, nitrogen is limiting
→ less productivity in ocean

(iii) maximum productivity: Tropical rain forest,
Coral reef

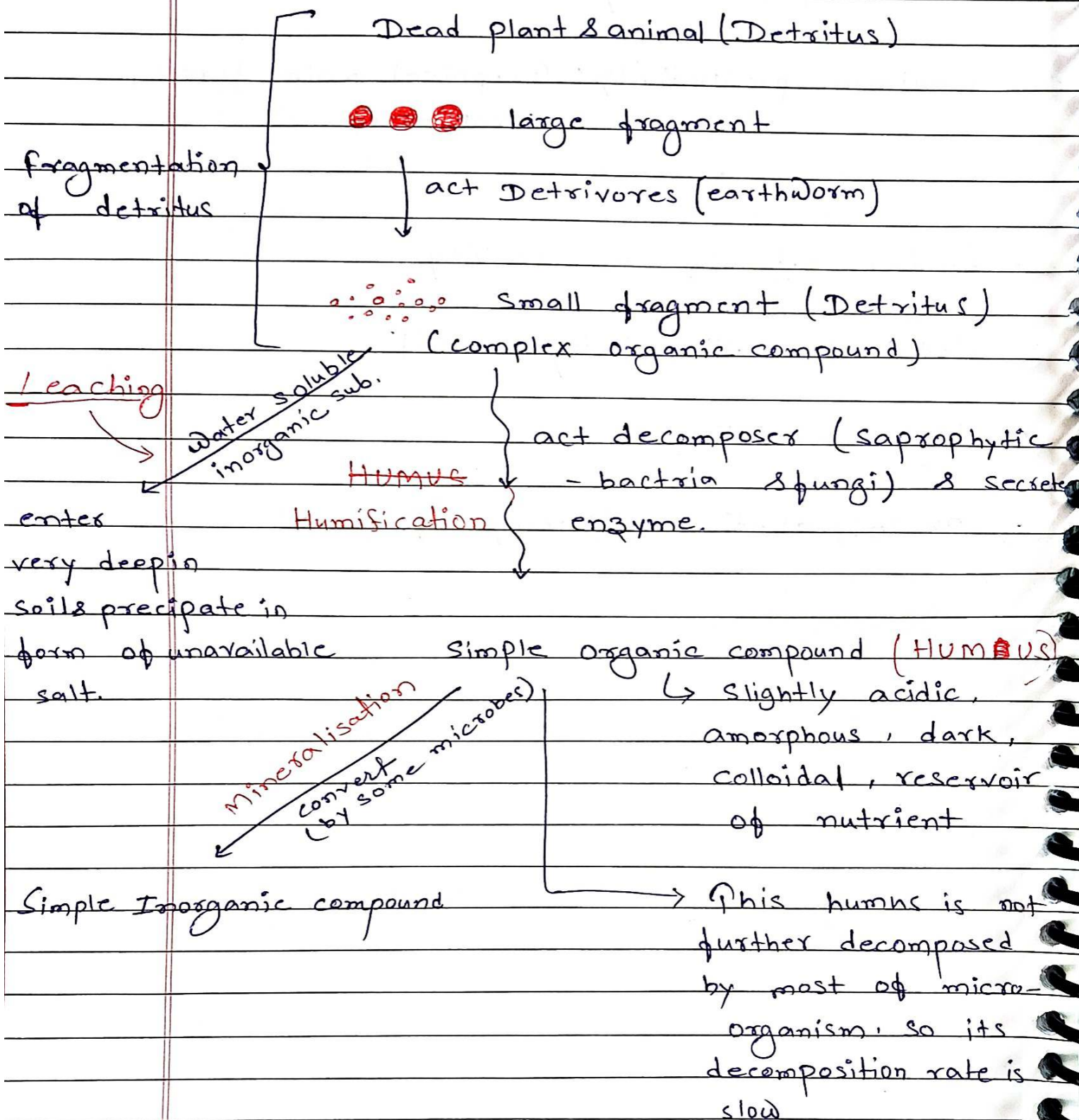
• Factors affecting productivity

① Nutrient availability in soil

② Light availability

③ photosynthetic efficiency of plant

* Decomposition

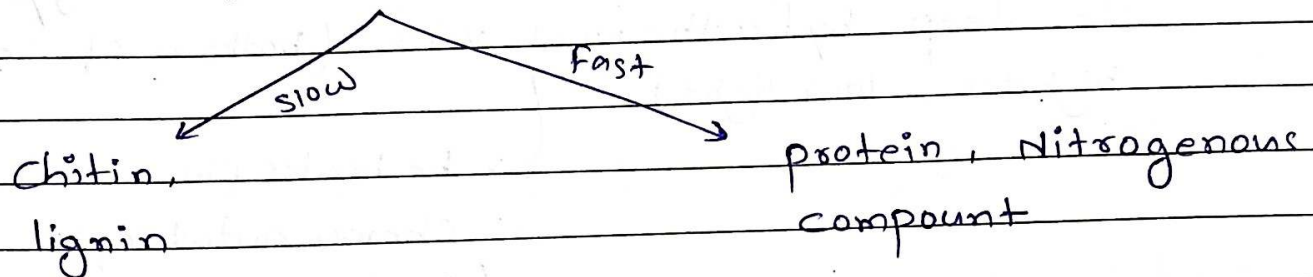


Catabolism

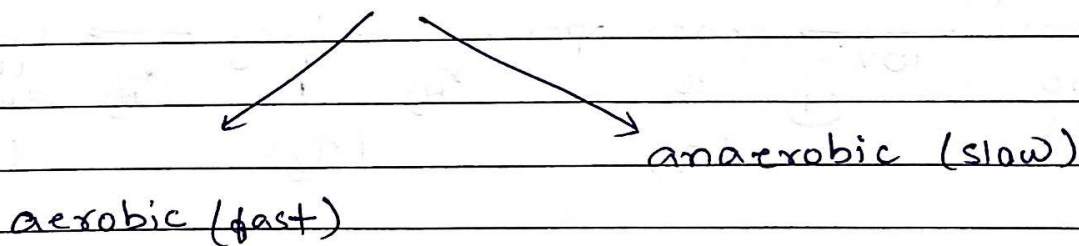
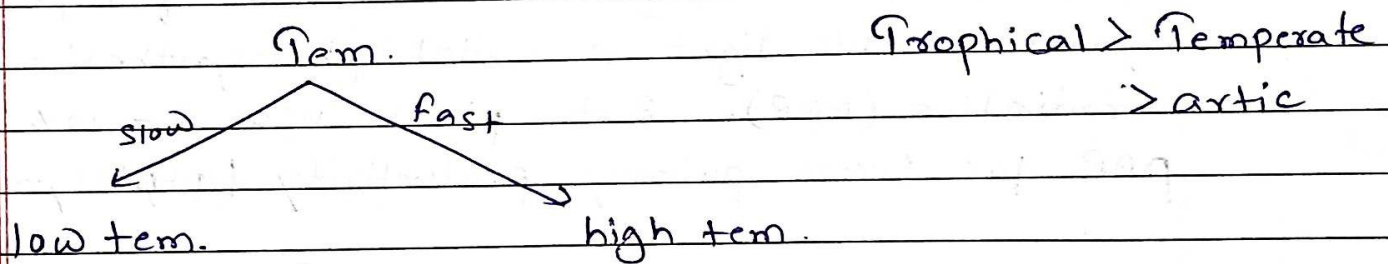
↳ Humification & mineralisation

* Factor affecting decomposition

(1) Chemical nature of detritus



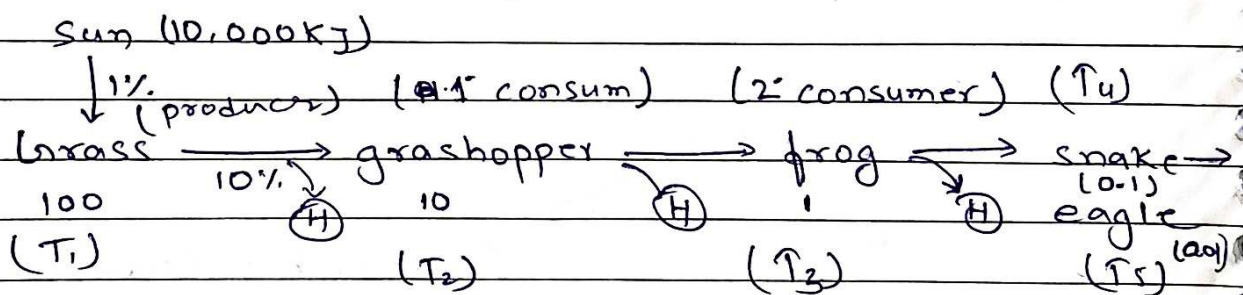
(2) Climate factor



* Energy flow

- The Sun is ultimate source of energy except in deep hydrothermal vent (bottom of sea, high tem, low light)
 - heterotrophs
 - chemo autotrophs (food synthesis by chemical energy)
- Less than 50% sunlight is available for photosynthesis. This light is called photosynthetically active radiation (PAR). But plant use 2-10% of PAR for gross primary productivity (photosynthesis)

Note:-



- Energy flow is unidirectional

10% Lindeman

Law

- 10% energy transfer from one trophic level to another (energy decrease)

- Respiration → breakdown of glucose

energy release

some part stored in form of ATP

loss in the form of heat

- loss of energy by: Heat, death, fecal matter
- Grass $\longrightarrow$ grasshopper $\longrightarrow$ frog $\longrightarrow$ snake
(Herbivores) (1st carnivores) (2nd carnivores)

• Energy follow Laws of Thermodynamic

1st Law: light energy convert into chemical energy of food.

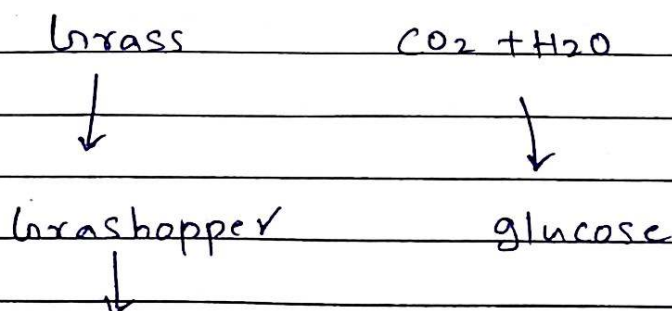
2nd Law: ~~Energy~~ loss energy (in form of heat) is not available for work done in system. and it create randomness & disorderness in surrounding. called entropy.

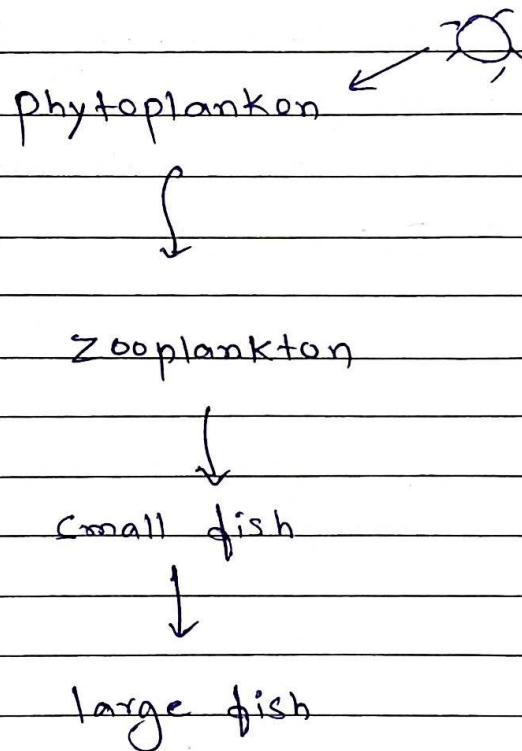
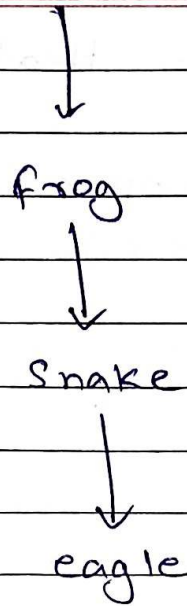
* Types of food chain

$\rightarrow$ Sequence of organism which consume particular organism & every organism consumed by other

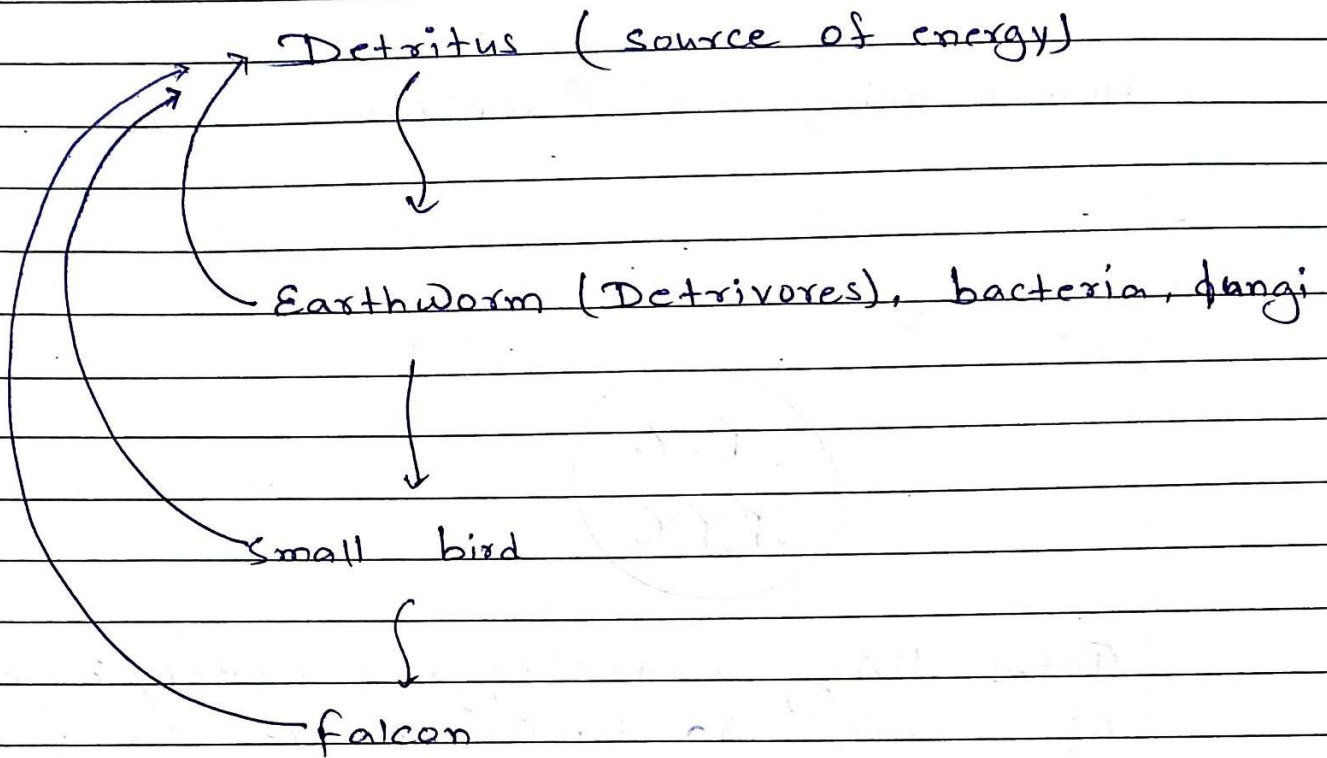
(1) Grazing food chain

- $\rightarrow$ Source of energy is Sun (Terrestrial ecosystem)
- $\rightarrow$ Unidirectional flow of energy
- $\rightarrow$ No. of trophic level is limited





② Detritus food chain



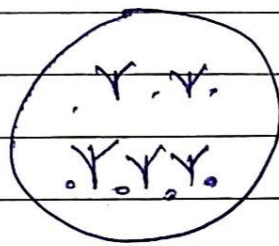
- Organic part convert into inorganic part.
- Energy flow is not unidirectional
- No limitation of trophic level

Note: Mem. of DFC can be eaten by LFC. So both DFC & LFC are interlink

- Terrestrial ecosystem: energy flow mainly by DFC
- In aquatic ecosystem flow of energy mainly by LFC

- Natural interconnection b/w food chain form food web.
- Human beings are Omnivores

* Standing crop



Total living matter/organic matter/biomass of organisms in particular area in particular time is called Standing.

• Biomass

↳ measure

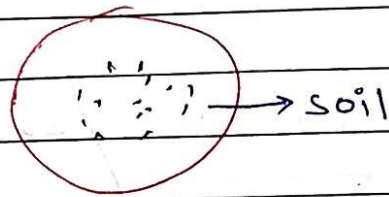
$$\text{Fresh wt} = \text{dry wt} + \text{H}_2\text{O}$$

$$\text{dry wt} = \text{Fresh wt} - \text{H}_2\text{O}$$

↳ accurate

(moisture content vary during different season so, it can affect fresh weight)

* Standing state



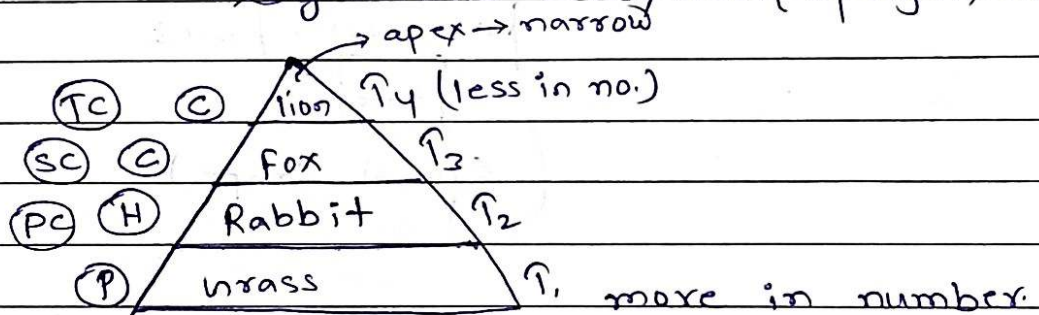
Total nutrient/inorganic part in area

* Ecological pyramid

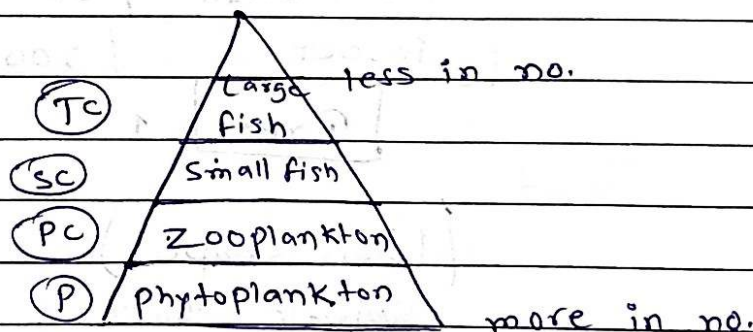
- Graphical representation of producer, herbivores, carnivores in term of number, bio mass & energy.
→ upright (mostly)

• pyramid of Number

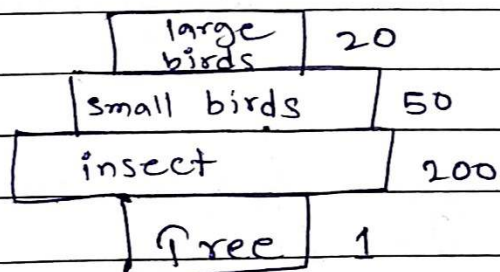
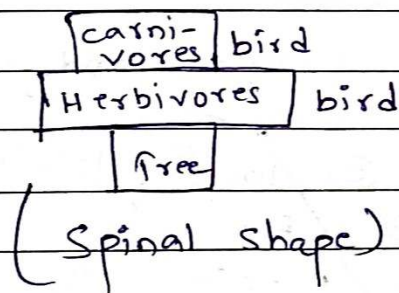
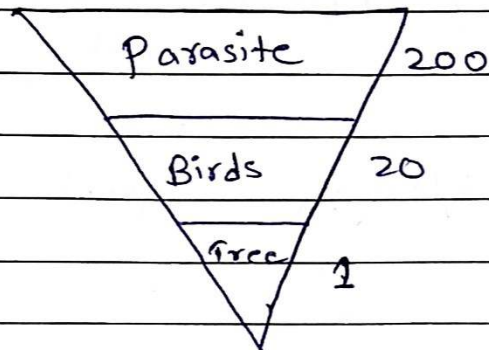
↳ ① grassland ecosystem (upright/straight)



② Aquatic ecosystem (upright/straight)



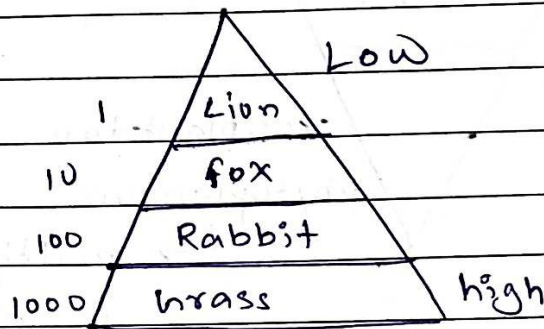
③ Tree Ecosystem.



(Urn shape)
+ Spindle shape

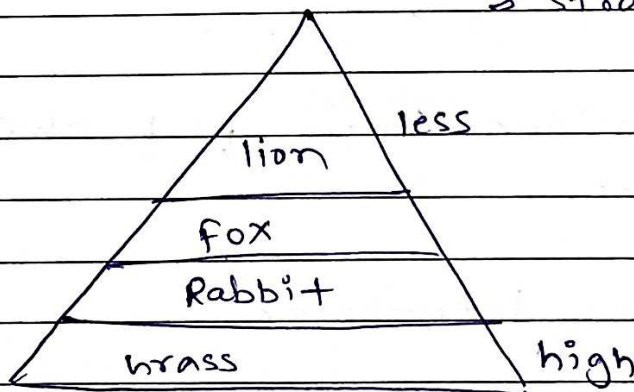
• pyramid of energy

↳ Always upright/straight

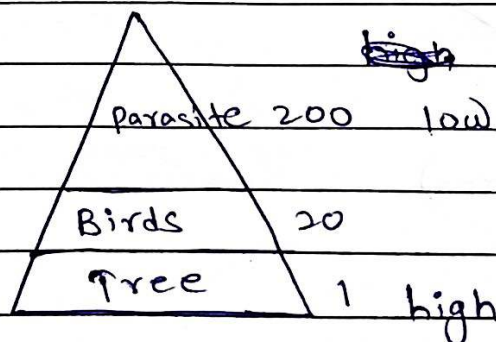


• pyramid of biomass (mostly upright/straight)

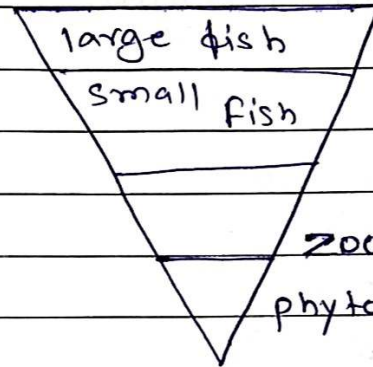
(a) Grassland ecosystem (upright & straight)



(b) Tree ecosystem



(c) Pond Ecosystem (Inverted)



→ multiplication rate is high. so many generation of pp eaten by single zp, so biomass increase.

• Limitation of pyramid.

→ generally consider simple food chain, not food web.

→ No place for decomposer

→ Organism (sparrow) can feed on two diffⁿ

